AD-A048 346 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/11
EARTHQUAKE RESISTANCE OF EARTH AND ROCK-FILL DAMS. REPORT 5. PE--ETC(U)
NOV 77 A G FRANKLIN, F K CHANG
UNCLASSIFIED WES-MP-S-71-17-5 NL

1 OF 1
AD
A048346

END
DATE
FILMED
2-78
DDC

MISCELLANEOUS PAPER S-71-17

EARTHQUAKE RESISTANCE OF EARTH AND ROCK-FILL DAMS

Report 5

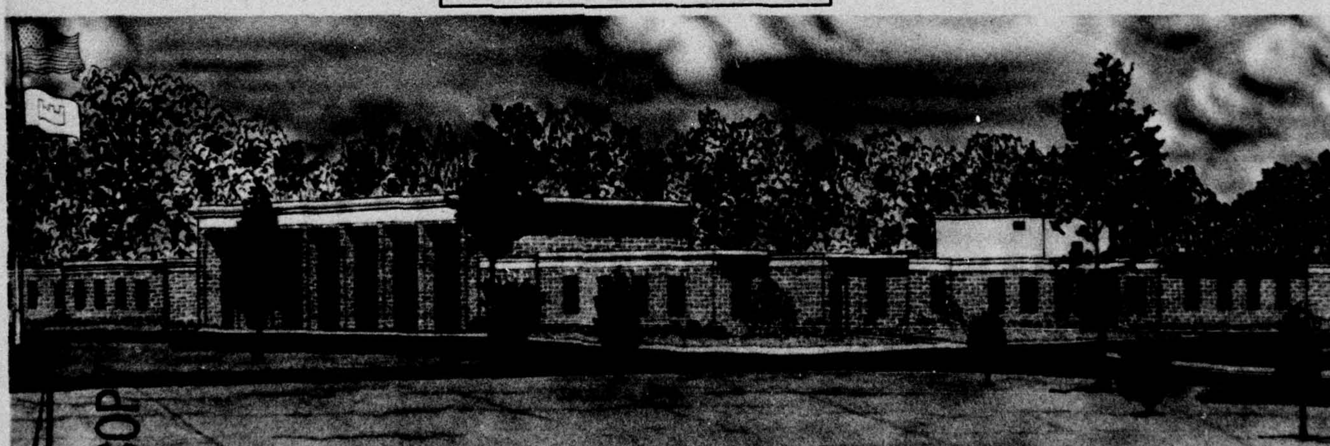
PERMANENT DISPLACEMENTS OF EARTH EMBANKMENTS BY NEWMARK SLIDING BLOCK ANALYSIS

by

Arley G. Franklin, Frank K. Chang

Soils and Pavements Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

November 1977
Report 5 of a Series



Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under CWIS No. 31144

Destroy this report when no longer needed. Do not return it to the originator.

748816

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
(9) Miscellaneous Paper S-71-17 ✓

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) EARTHQUAKE RESISTANCE OF EARTH AND ROCK-FILL DAMS. Report 5. PERMANENT DISPLACEMENTS OF EARTH EMBANKMENTS BY NEWMARK SLIDING BLOCK ANALYSIS.

5. TYPE OF REPORT & PERIOD COVERED
Report 5 of a series

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) Arley G. Franklin
Frank K. Chang

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
P. O. Box 631, Vicksburg, Miss. 39180 ✓

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
CWIS No. 31144

11. CONTROLLING OFFICE NAME AND ADDRESS
Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

12. REPORT DATE
(11) November 1977

13. NUMBER OF PAGES
59

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(14) WES-MP-S-71-17-5

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

(12) 63p.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Dam stability
Displacement
Earth dams
Earthquake engineering
Earthquake resistant structures

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In 1965, Newmark described methods for computing permanent displacements of embankments subjected to earthquake loading, and provided a chart for estimating the upper bounds of permanent displacements on the basis of a sliding block model and four earthquake records. Since that time, many additional strong-motion records have been obtained in the western United States, and it was decided to extend the data base for Newmark's chart by making use of these records. For this purpose, a computer program was written to integrate the

(Continued)

038 100

LB

20. ABSTRACT (Continued).

digitized accelerograms and compute the permanent displacements from the velocity-time history and the resistance coefficients. All records were scaled to 0.5g peak acceleration and 30-in./sec peak velocity, and the resulting scaled permanent displacements are called standardized maximum displacements. A total of 169 horizontal and 10 vertical corrected accelerograms were processed in addition to several synthetic records.

The greatest standardized maximum displacements, computed from records of the magnitude-6.5 San Fernando earthquake of 9 February 1971 on soil sites, were about 1.5 times above Newmark's upper bound, while those for all other earthquakes analyzed were near or below Newmark's upper bound. The maximum values computed from the Jennings et al. synthetic record for a magnitude 8+ earthquake were about 1.7 times higher than Newmark's upper bound. Those for the Seed-Idriss synthetic record fell slightly below those for the Jennings et al. synthetic records. Ten records from rock sites compared with 47 records from soil sites indicate that permanent displacements on rock sites are about 75 percent of those on soil sites from earthquakes of the same magnitude, peak acceleration, and peak velocity. It was found that standardized maximum displacements were roughly proportional to the duration of shaking, and consequently were positively correlated with earthquake magnitude.

Appendixes A and B list the earthquakes and the ground motion data used, respectively. Appendix C presents data on the synthetic records.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

This report is part of ongoing work at the U. S. Army Engineer Waterways Experiment Station (WES) in the Civil Works Program, "Earthquake Resistance of Earth and Rock-fill Dams," CWIS No. 31144, sponsored by the Office, Chief of Engineers, U. S. Army. This report was prepared by Dr. Arley G. Franklin and Mr. Frank K. Chang of the Earthquake Engineering and Vibrations Division, Soils and Pavements Laboratory (S&PL), under the general direction of Mr. James P. Sale, Chief, S&PL, and Dr. Francis G. McLean, Chief, Earthquake Engineering and Vibrations Division.

Directors of WES during the period of this study were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

	Page
PREFACE	2
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT	4
PART I: INTRODUCTION	5
PART II: METHOD OF ANALYSIS	7
Concepts of Newmark's Method	7
Computation of Permanent Displacements	13
Scaling	15
PART III: RESULTS	21
Upper Bounds of Permanent Displacements	27
Correlation with Magnitude and Duration	27
Correlation with Epicentral Distance	30
Synthetic Earthquakes	30
PART IV: SUMMARY AND CONCLUSIONS	36
REFERENCES	38
APPENDIX A: LIST OF EARTHQUAKE EVENTS	A1
APPENDIX B: STRONG-MOTION DATA, EARTHQUAKES OF WESTERN UNITED STATES, UNIFORMLY PROCESSED AT CALIFORNIA INSTITUTE OF TECHNOLOGY	B1
APPENDIX C: SYNTHETIC EARTHQUAKE RECORDS	C1
APPENDIX D: NOTATION	D1

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
inches per second	2.54	centimetres per second

EARTHQUAKE RESISTANCE OF EARTH AND ROCK-FILL DAMS

PERMANENT DISPLACEMENTS OF EARTH EMBANKMENTS BY NEWMARK SLIDING BLOCK ANALYSIS

PART I: INTRODUCTION

1. In his 1965 Rankine Lecture, "Effects of Earthquakes on Dams and Embankments," Newmark[1] described simple concepts for computing the displacement of a sliding mass in an embankment subjected to earthquake accelerations. He also presented charts, based on a sliding block model, for estimating the upper bounds of potential permanent displacements due to an earthquake with a given peak acceleration and peak particle velocity. The calculations from which these charts were derived were based on ground motions from four earthquake accelerograms. Since Newmark's 1965 lecture, the Parkfield earthquake, with 0.5g recorded on the San Andreas Fault, and the San Fernando earthquake, with 1.25g recorded in the epicentral region, have occurred, and a large number of strong-motion accelerograms have been collected from these and other events. It was decided to use these records to extend the data base for Newmark's charts.

2. Newmark presented charts for the cases of symmetrical and non-symmetrical resistance to sliding. The case of symmetrical resistance can be of only infrequent occurrence, and leads to limited permanent deformations. It was judged to be of minor interest, and only the second case, that of a sliding block moving downslope, was dealt with in this study.

3. A total of 169 horizontal and 10 vertical strong-motion records from 27 earthquakes and 10 synthetic accelerograms were used with the sliding block analysis, and the results are presented in Part III. Listings of the earthquakes and the ground motion data used are given in Appendixes A and B, respectively, and Appendix C presents data on the synthetic records.

PART II: METHOD OF ANALYSIS

Concepts of Newmark's Method

4. A case of potential sliding of a portion of an embankment under earthquake loading is illustrated in Figure 1. The effective force resulting from the critical earthquake acceleration is the force NW in Figure 1. This force is the product of the weight W* of the sliding mass and the fraction N of gravitational acceleration g that is required to reduce the factor of safety to unity. The direction of the force, defined by its angle of inclination to the horizontal, θ, is the most critical direction, or that which results in a minimum value for N. The angle θ is normally no more than a few degrees. According to Sarma,[2] both the factor of safety and the permanent displacements are insensitive to θ, and it can be taken as zero with little error. The value of N, the critical acceleration or resistance coefficient, can be found by means of conventional methods of stabiliity analysis, such as Bishop's Method, the Morgenstern-Price method, etc., using appropriate undrained strength values. Various trial values of N may be used so as to find the value that makes the factor of safety equal to unity. Plane, circular, or other forms of slip surface may be considered. The method of stability analysis described by Sarma[2] uses a slip surface of arbitrary shape and determines the value of N directly.

5. The force polygon for the sliding mass is shown in Figure 2b.

---

* For convenience, symbols and unusual abbreviations used in this report are listed and defined in the Notation (Appendix D).

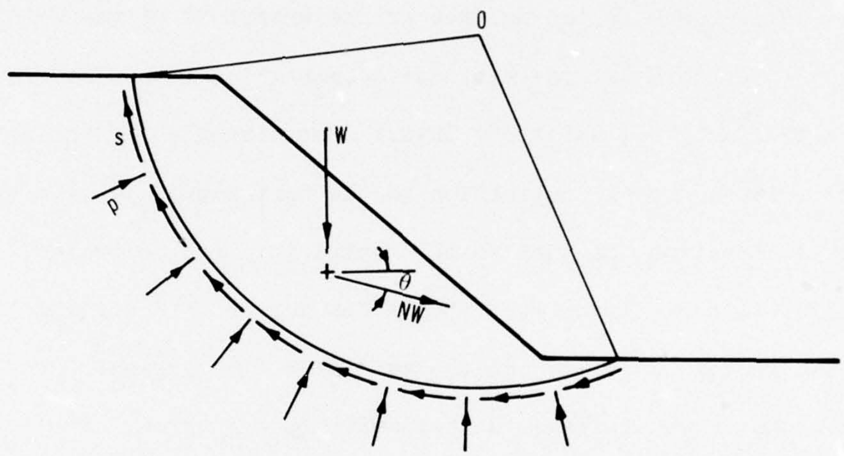
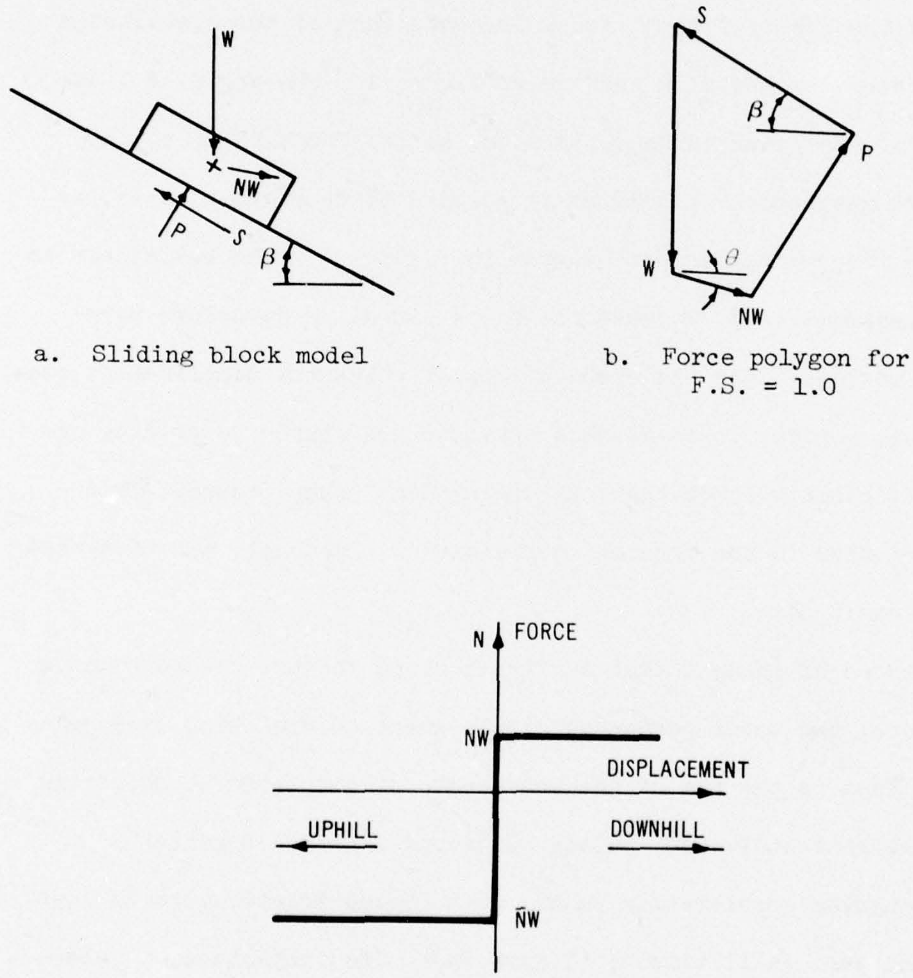


Figure 1. Potential sliding mass



a. Sliding block model

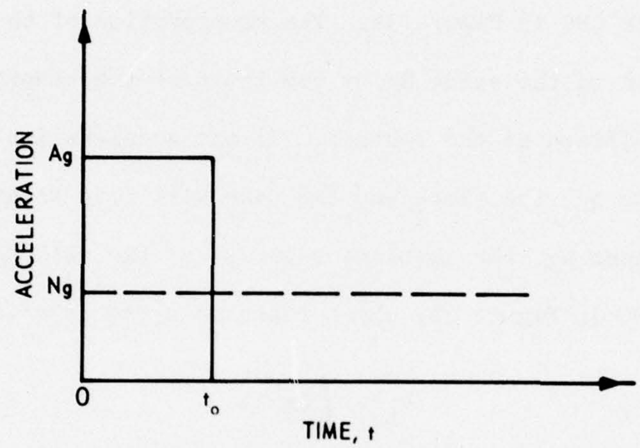
b. Force polygon for F.S. = 1.0

c. Force-displacement relation

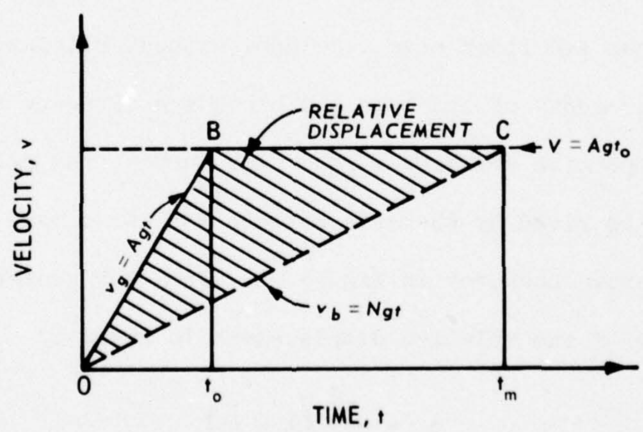
Figure 2. Mechanical model for displacement analysis

The same force polygon can also represent the forces on a rigid block that is about to slide down an inclined plane, as shown in Figure 2a. In the condition illustrated, the base is undergoing an acceleration Ng to the left and upward, the shearing resistance S has reached its limiting value, and slippage of the block relative to the plane is imminent, or, in other words, the factor of safety is unity. The force P is the resultant of the normal forces, and S the resultant of the distributed shear resistance, on the slip surface of Figure 1. The angle β , the inclination of the plane surface, is found as the inclination of the force S. The resistance to sliding is assumed to be rigid-plastic, as shown in the force-displacement diagram in Figure 2c. The resistance to sliding is unsymmetrical, because the block can slide downslope more easily than upslope. For the computations of permanent displacement presented in this report, it is assumed that the resistance to sliding upslope is sufficiently large that upslope sliding never occurs. This assumption results in the greatest permanent displacement, and thus represents the worst case.

6. For an embankment that suffers a slope failure due to seismic ground motions, the total permanent displacement of a sliding mass relative to the base is the sum of the increments of displacement occurring during a number of individual pulses of ground motion. Consider a single rectangular acceleration pulse, with ground acceleration Ag lasting from time zero until time t_o (Figure 3a). The instantaneous velocity of the ground, which is given by



a. Rectangular acceleration pulse



b. Relative displacement due to rectangular acceleration pulse

Figure 3. Newmark's displacement concepts

$$v_g = \int Ag\ dt\ ,\ (0 \le t \le t_o)$$
$$v_g = Agt_o\ ,\ (t \ge t_o) \tag{1}$$

follows the path OBC in Figure 3b. The acceleration of the sliding block is limited to the value Ng by the limit of the shearing resistance that can be mobilized at the contact. If the acceleration Ag is less than or equal to Ng, the block and the base will move together; but if Ag is greater than Ng, the absolute velocity of the sliding block follows the path OC in Figure 3b, which represents the relation

$$v_b = \int Ng\ dt \tag{2}$$

Relative motion between the base and the block continues until both attain the same absolute velocity, which occurs at time t_m. From that time on, the base and block move together, without slippage. Since the absolute displacements of the base and block are given by the areas under their respective velocity versus time curves, the relative displacement, u_m, is given by the area between the two curves, the triangle OBC, which is shown hachured in Figure 3b. From the geometry of the diagram, the value of the relative displacement is given by

$$u_m = \frac{V^2}{2gN}\left(1 - \frac{N}{A}\right) \tag{3}$$

where V is the maximum ground or base velocity, which is equal to Agt_o. If nothing happens to produce further relative motion, or reverse it, the relative displacement will be permanent, and will thus be called permanent displacement.

Computation of Permanent Displacements

7. The computation of the permanent displacement, u_m, from an earthquake record can be visualized from the plot shown in Figure 4. A plot of this type can also be used to perform the computation graphically. The curve $v_g(t)$ represents the ground or base velocity (the velocity of the ground beneath the sliding mass), while the critical acceleration for the sliding mass is represented by a slope, $dv/dt = Ng$, on the velocity versus time plot. Wherever the ground acceleration (slope of the ground velocity curve) exceeds the critical acceleration, the velocity curve of the sliding mass departs from that of the ground and follows a linear path, $v_b = Ngt$, until the two velocities again become equal, at which time relative movement ceases. The total permanent displacement, u_m, is then given by the sum of the areas between the two velocity curves.

8. In Newmark's 1965 Rankine Lecture, results were presented for scaled permanent displacements computed from four strong-motion records which were available at that time. The four earthquake records were first scaled to a maximum acceleration of 0.5g and a maximum ground velocity of 30 in./sec* by adjusting the acceleration and time scales. The resulting scaled values of relative displacement, called standardized maximum displacements, were plotted against the ratio N/A on a logarithmic plot, and upper bound curves were proposed for various ranges in the value of N/A.

---

* A table of factors for converting U. S. customary units to metric (SI) units of measurement is found on page 4.

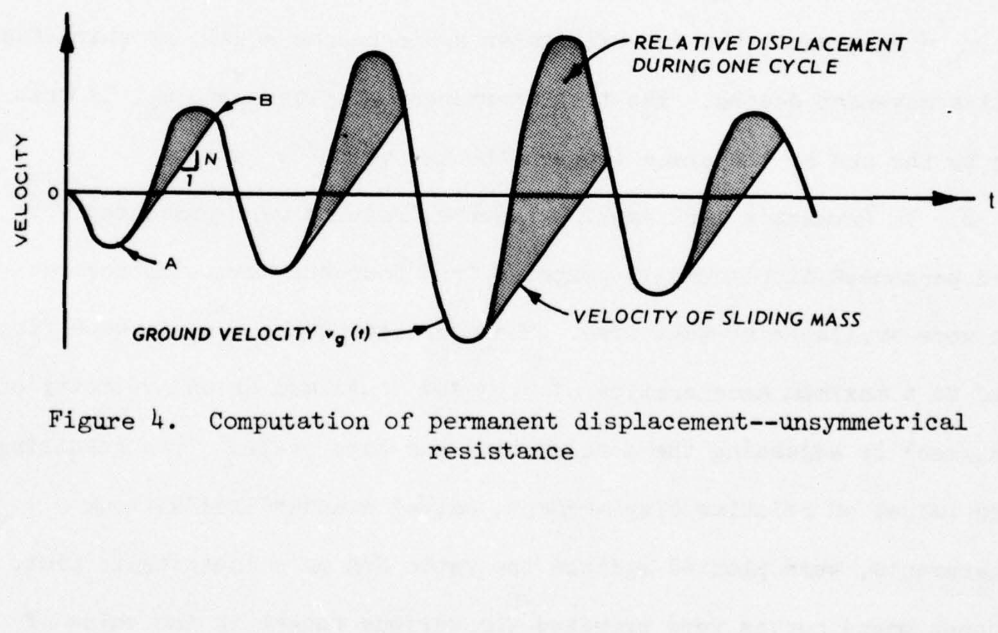


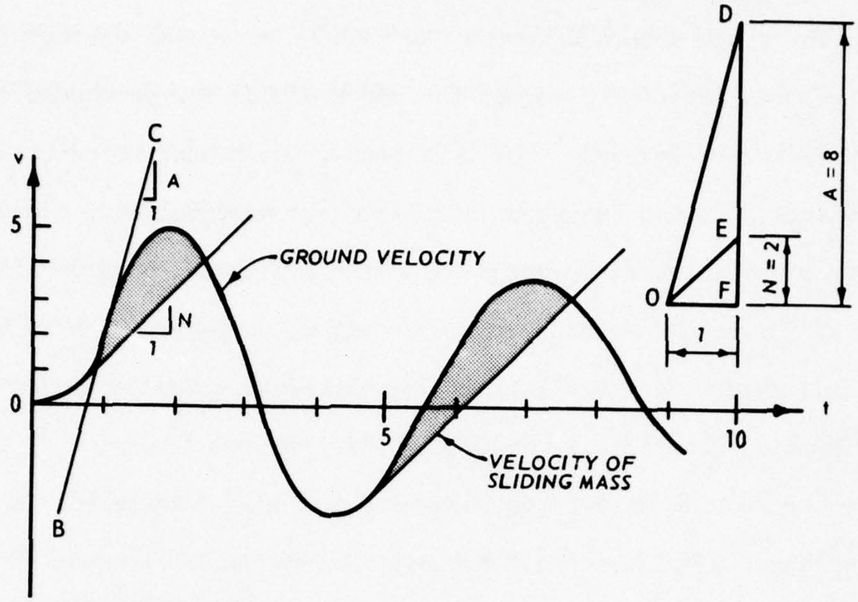
Figure 4. Computation of permanent displacement--unsymmetrical resistance

9. Since 1965, many additional strong-motion records have become available. The study reported herein was made to determine whether these additional records materially affect the upper bounds for permanent displacement proposed by Newmark. For this study, the ground velocities, ground displacements, and permanent displacements were computed numerically, using the trapezoidal rule, by means of a simple computer program written in Fortran IV for the G. E./Honeywell 635 digital computer. The ground motion records used were 179 digitized, baseline-corrected accelerograms of the California Institute of Technology (CIT) Volume II series.[3] The four earthquake records used by Newmark were included. Agreement in computed permanent displacements for these records was close, but not exact, probably because of some differences in the form of the earthquake records used.

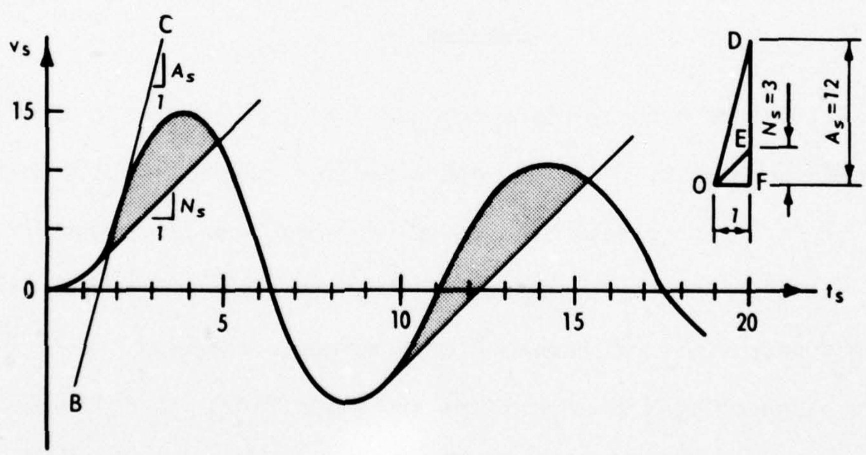
Scaling

10. All of the strong-motion records used were scaled to obtain a maximum ground acceleration of 0.5g and a maximum ground velocity of 30 in./sec, in order to obtain results of the same form as Newmark's.

11. The purpose of the scaling of the earthquake records is to permit direct comparison of permanent displacements computed from records with a wide range of peak accelerations and velocities. The process can be illustrated graphically with a hypothetical example including numerical values, as shown in Figure 5. Suppose that a portion of an earthquake record is represented by a velocity versus time plot (which is normally obtained by integration of the acceleration record) as shown in Figure 5a, and that the peak acceleration has been identified by a



a. Hypothetical velocity record at natural scale



b. Hypothetical velocity record scaled to $v_s/v = 3$ and $A_s/A = 1.5$

Figure 5. Hypothetical velocity records, showing scaling to arbitrary peak acceleration and peak velocity values, for A/N = 4

tangent BC to the velocity curve at the point of maximum slope. It can be seen that the peak velocity V is represented as 5, and the peak acceleration A as 8. (The values have been chosen for numerical convenience and simplicity, rather than realism, and units of measurement have been dispensed with). Suppose also that the geometric construction has been made on the record for the computation of the permanent displacement of a sliding mass whose critical acceleration N is 2; the ratio A/N is thus 4. The relation between these acceleration values is also illustrated by the diagram ODEF at the right-hand side of the figure. In the diagram, if the base OF of the triangle represents unit time, then the altitude DF, measured along the velocity axis, represents the peak acceleration A, and the altitude EF represents the critical acceleration N. Just as previously described for Figure 4, the shaded areas between the curves represent increments of permanent displacement of the sliding mass relative to the ground or base, and the sum of these increments is the total permanent displacement, u_m.

12. Scaling this record to arbitrarily chosen standard values of peak velocity and acceleration is done by adjusting the accelerations and the time scale; however, it is equivalent to performing the following two operations:

<u>a</u>. Transforming the ordinate (velocity axis) by scaling it so that the highest peak on the velocity curve corresponds to the desired peak velocity. The value chosen for the example is 15 (see Figure 5b).

b. Transforming the abscissa (time axis) by scaling it so that the slope of the line representing the peak acceleration has the desired value. In the example, a peak acceleration of 12 was chosen. In other words, the acceleration diagram is scaled so that the distance DF equals 12 units on the new velocity axis; the distance OF then represents one time unit.

Another way of looking at this scaling is to note that it is dimensionally correct to write a velocity as the product of an acceleration and a time, or

$$v = at \tag{4}$$

Therefore,

$$\frac{V_s}{V} = \frac{A_s}{A} \cdot \frac{t_s}{t} \tag{5}$$

which gives

$$\frac{t_s}{t} = \frac{V_s}{V} \cdot \frac{A}{A_s} \tag{6}$$

in which the subscript s denotes scaled values. For the example, the required time scaling is

$$\frac{t_s}{t} = \frac{15}{5} \cdot \frac{8}{12} = 2 \tag{7}$$

13. The resulting transformed velocity record, as shown in Figure 5b, is identical with the original except for the scaling of the coordinate axes, and examination of the figure will show that the desired relationships among accelerations, velocities, and displacements are all present. Note particularly that in the transformation of the peak acceleration A to a scaled peak acceleration A_s, the critical acceleration of the sliding mass, N, is scaled in the same proportion, so that the ratio N_s/A_s is the same as N/A.

14. The relationship between the permanent displacement u_m and its representation on the scaled plot, which is shown as u_s, is apparent from a comparison of Figures 5a and 5b. The scale relationship between the areas is equal to the product of the horizontal and vertical linear scales; thus,

$$\frac{u_m}{u_s} = \frac{V}{V_s} \cdot \frac{t}{t_s} \tag{8}$$

Substituting for the time scaling the expression derived earlier,

$$\frac{t_s}{t} = \frac{V_s}{V} \cdot \frac{A}{A_s} \tag{9}$$

gives

$$\frac{u_m}{u_s} = \frac{V^2 A_s}{V_s^2 A} \tag{10}$$

For the relation between the standardized maximum displacement u_s and the unscaled permanent displacement u_m, $V_s = 30$ in./sec and $A_s = 0.5g$ are used, which gives

$$u_m = u_s \cdot \frac{V^2(0.5g)}{(30)^2 Ag}$$

$$= u_s \cdot \frac{V^2}{1800A} \tag{11}$$

where V is the maximum ground velocity, in inches per second; A is the maximum ground acceleration, as a fraction of g, in the unscaled record; and u_s and u_m are in inches.

PART III: RESULTS

15. Representative results from the analysis of a total of 169 horizontal and 10 vertical accelerograms from 27 strong earthquake events of the western United States are plotted in Figures 6 through 10, and discussed in the following sections. In addition, computations were made for the Jennings et al.[4] (CIT) and Seed-Idriss[5] synthetic accelerograms, and for a synthetic record developed to fit the Nuclear Regulatory Commission Regulatory Guide 1.60 spectra.[6] Total displacement was also correlated with Richter magnitude, duration, and distance.

16. Figures 6 through 10 show the standardized maximum displacement, u_s, versus the value of $\frac{N}{A}$ (where A and N are as previously defined) for about half of the earthquake records analyzed, and include those that yielded the highest values of displacement. Figure 6 shows results from 9 accelerograms of the Kern County, California, earthquake of 21 July 1952, at distances of 43 to 126 km and at soil sites. Figure 7 contains the results from 47 accelerograms of the San Fernando earthquake of 9 February 1971 at distances of 22.4 to 185 km, at soil sites. Figure 8 presents the results of 15 records of western United States earthquakes of magnitudes M 5.2 to 6.0, at soil sites. Figure 9 represents 10 vertical components of the 1971 San Fernando earthquake. Figure 10 represents 10 records of various western United States earthquakes at rock sites. To permit comparisons with the records not shown in these plots, Appendix B lists the values of standardized maximum displacement for three values of N/A for all records analyzed.

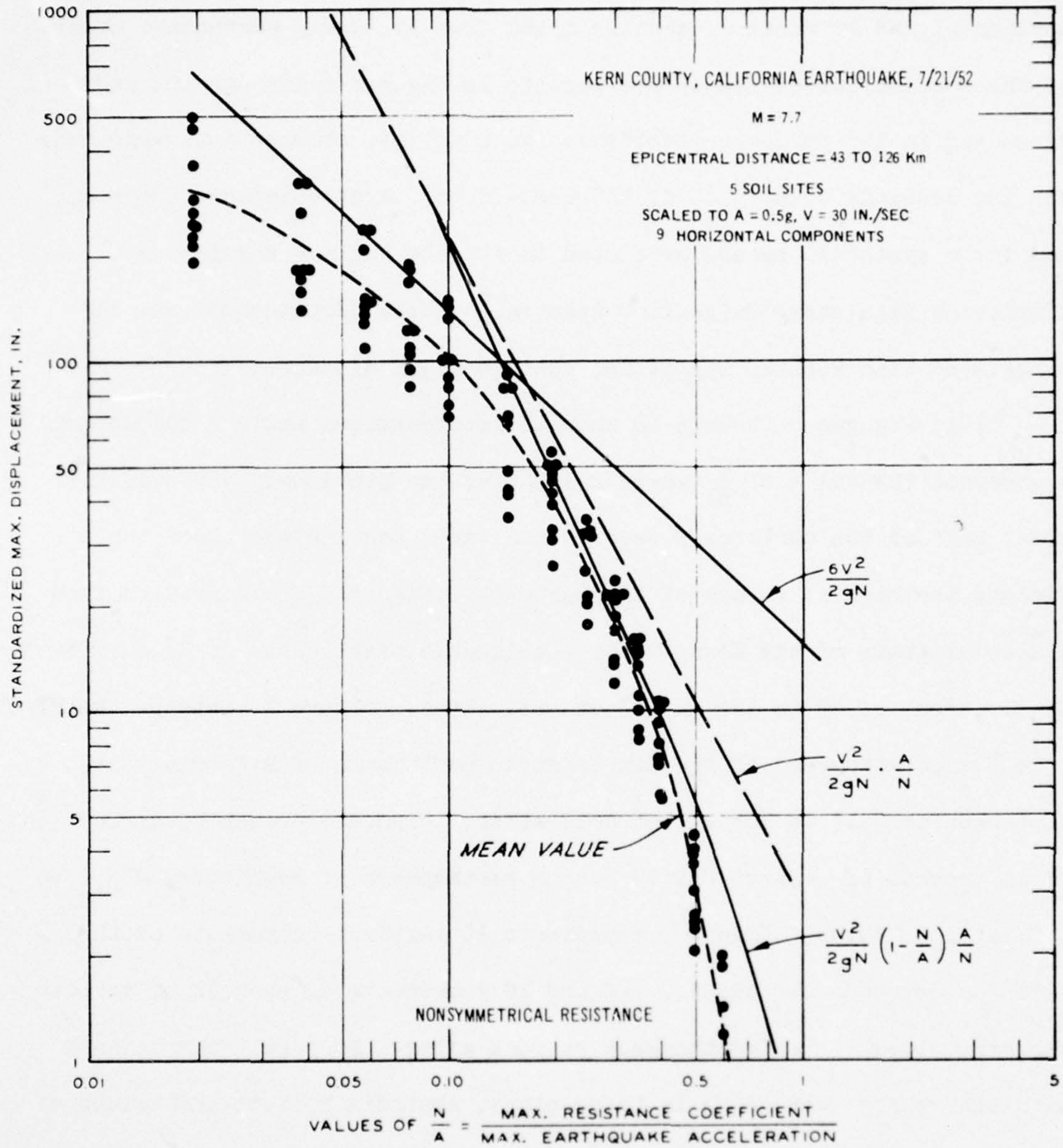


Figure 6. Permanent displacements due to Kern County earthquake, 21 July 1952 (soil sites)

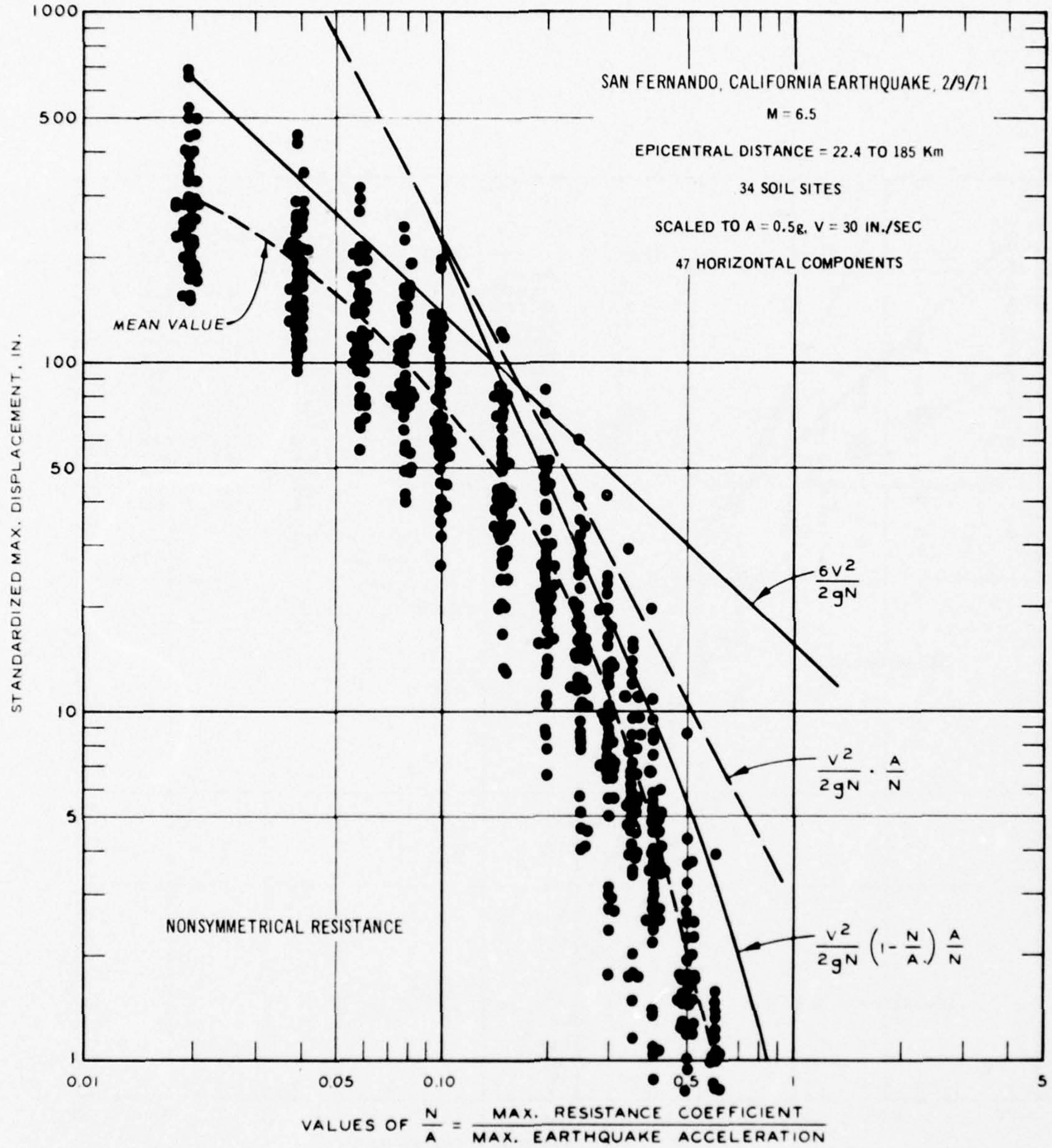


Figure 7. Permanent displacements due to San Fernando earthquake, 9 February 1971 (soil sites)

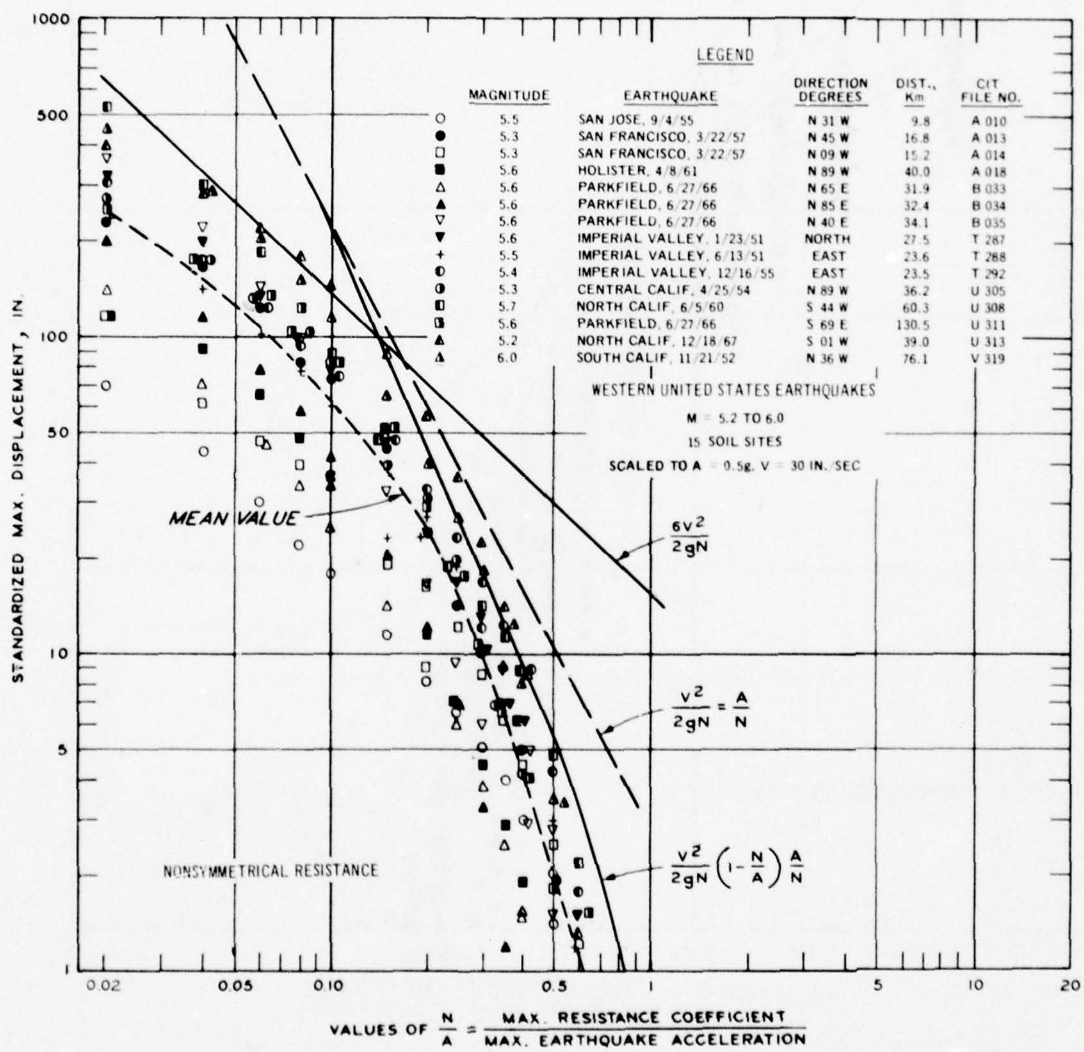


Figure 8. Permanent displacements due to western United States earthquakes of magnitudes 5.2 to 6.0

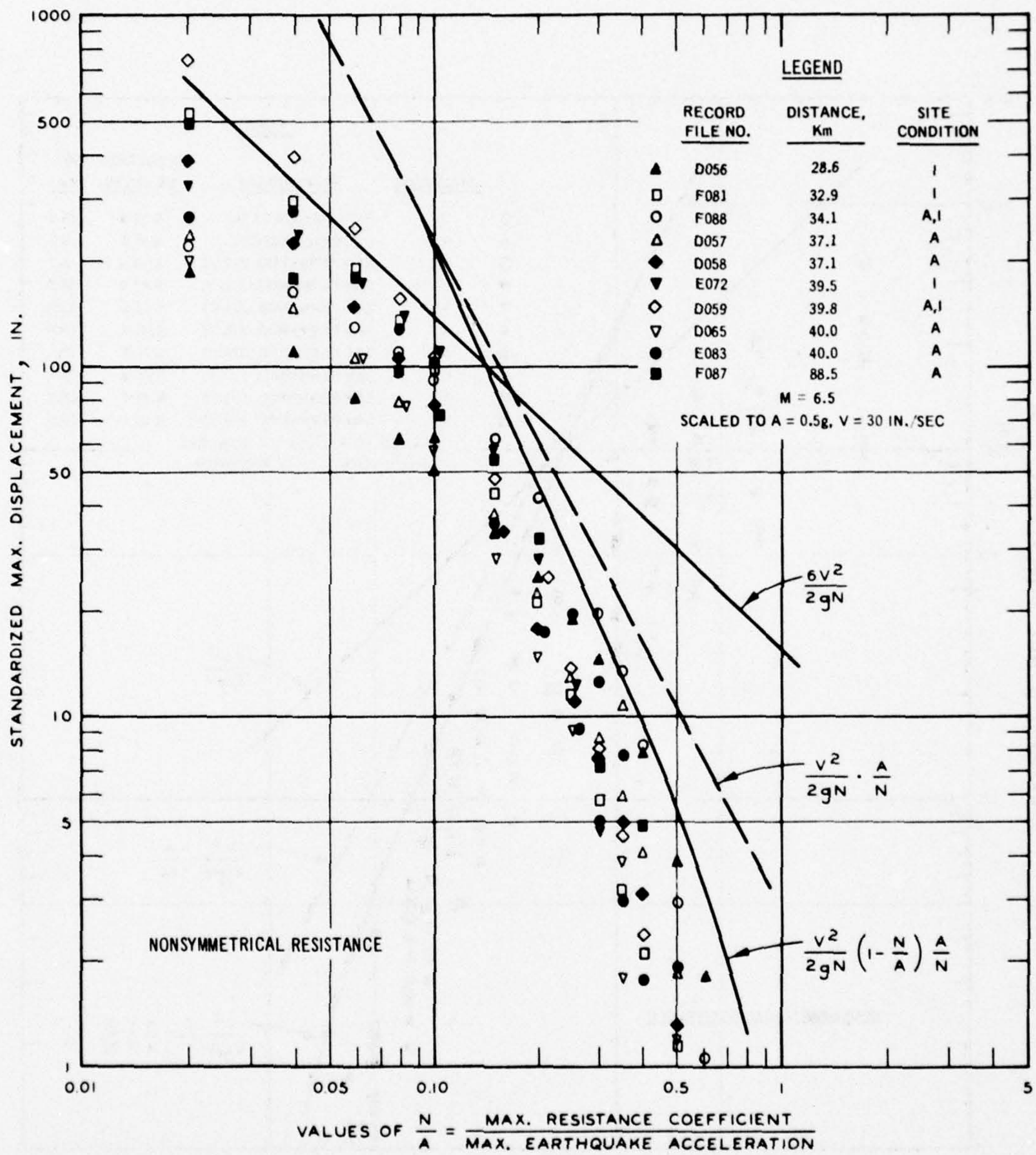


Figure 9. Permanent displacement due to San Fernando earthquake, 9 February 1971 (alluvial and intermediate sites), computed from vertical component records

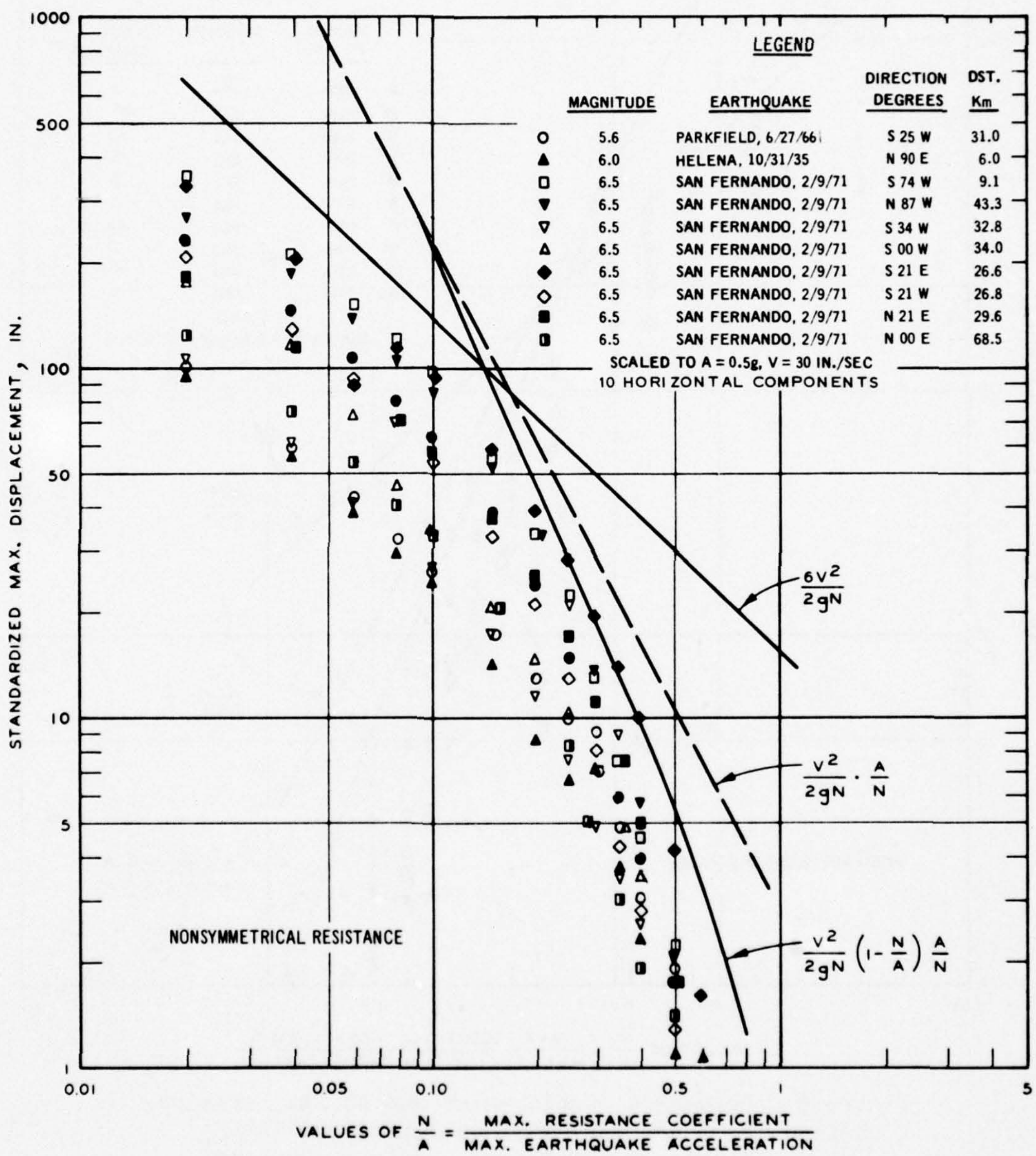


Figure 10. Permanent displacements computed from rock site accelerograms

Upper Bounds of Permanent Displacements

17. Figures 6 through 10 show, in addition to the values of u_s versus N/A, three curves chosen by Newmark to represent upper bounds for u_s as computed from the four earthquake records used in his 1965 paper. In Figures 6 through 9, there are several points, the highest belonging to the 1971 San Fernando earthquake, lying above Newmark's upper bound curves. It can be seen from these figures that in order to envelope the permanent displacements computed from the present data, the bounding curves must be raised.

18. Figure 10, while based on only 10 records from three earthquakes, suggests that permanent displacements at rock sites will be appreciably lower than at soil sites, for earthquakes of equal magnitude and peak motion values, and for all of the values shown are conservatively bounded by Newmark's upper two curves.

Correlation with Magnitude and Duration

19. The computed values of standardized maximum displacement, when plotted against duration of shaking, as shown in Figure 11 for the soil site records of the San Fernando earthquake, can be seen to be approximately proportional to the duration. The duration for this purpose was considered to be the period lasting until the last acceleration peak with at least 0.25 times the peak acceleration. Plots of values from other earthquake records (not shown here) are similar. Because duration of shaking correlates positively with earthquake magnitude, the standardized maximum displacement values can also be expected to increase with magnitude. This tendency is illustrated in Figure 12, in which mean value curves

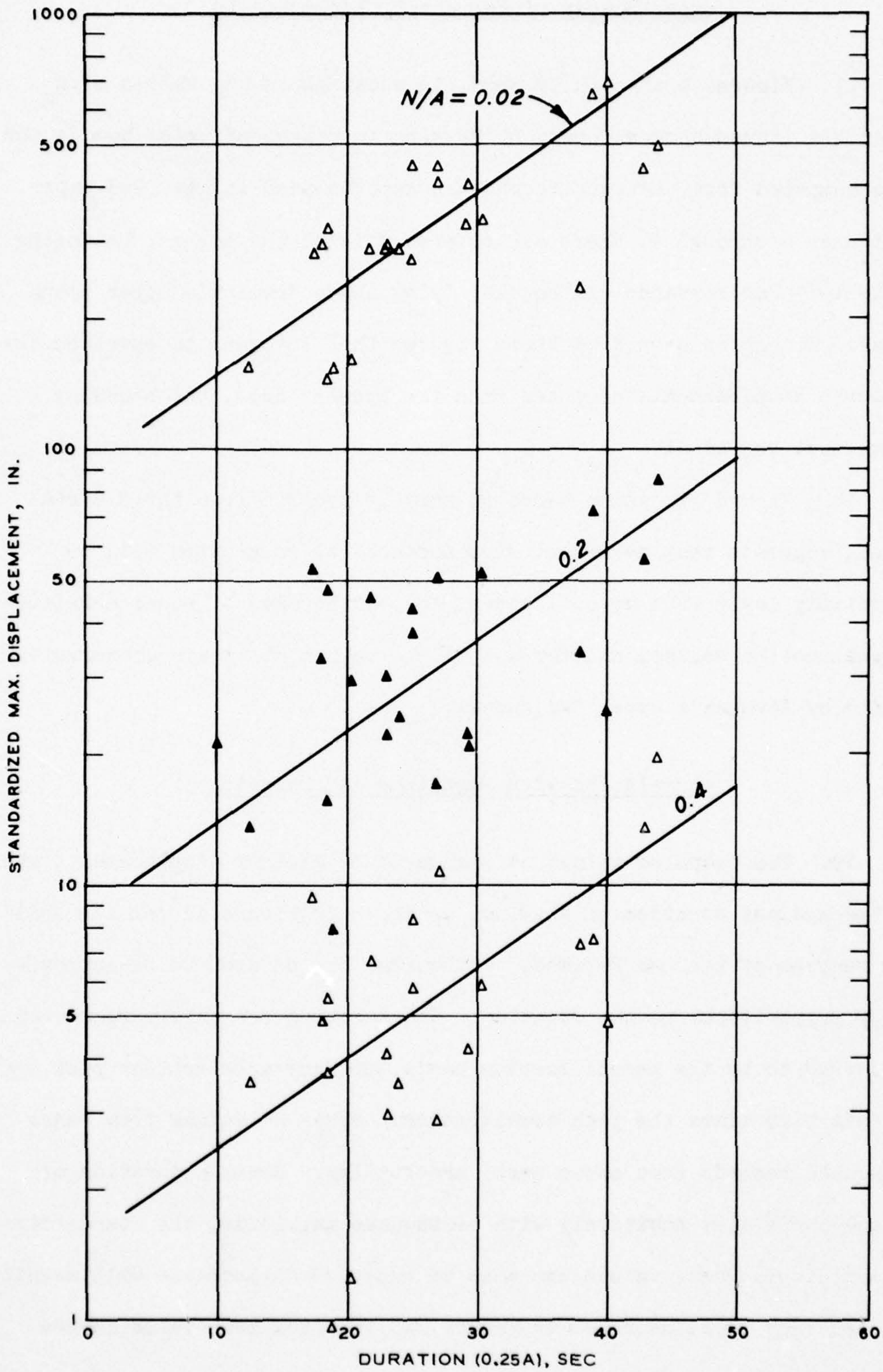


Figure 11. Permanent displacement versus duration, San Fernando earthquake, 9 February 1971 (soil sites)

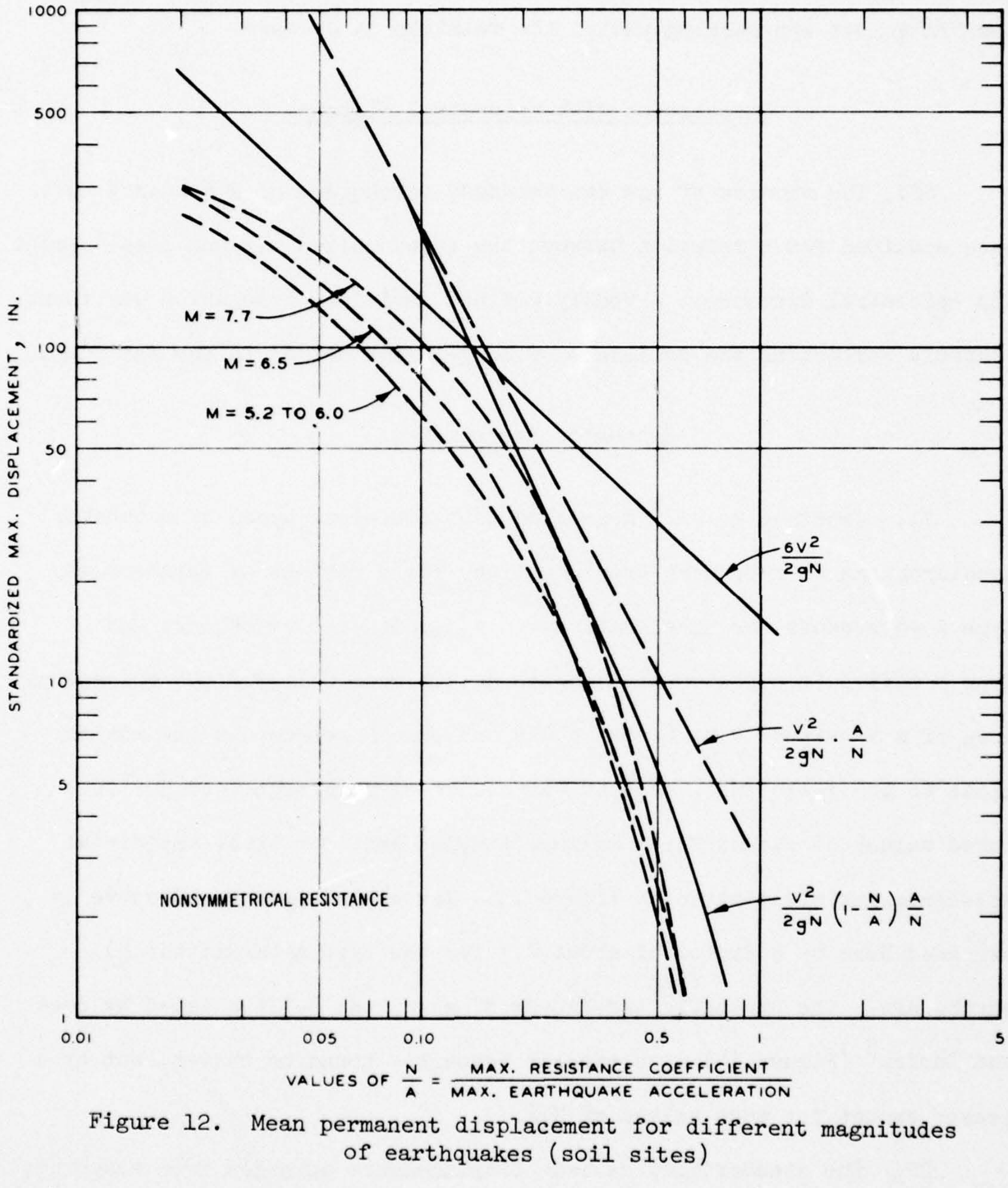


Figure 12. Mean permanent displacement for different magnitudes of earthquakes (soil sites)

for the earthquakes of Figures 6, 7, and 8 have been plotted. The systematic variation with magnitude, as reflected by the mean values, is small compared to the scatter band for a single earthquake, however; and for N/A values approaching unity, the relation is obscure.

Correlation with Epicentral Distance

20. The records of the San Fernando earthquake of 9 February 1971 were examined for a relation between the standardized maximum displacement and epicentral distance. A weakly defined positive correlation was found, probably reflecting the dominance of long-period motion in the far field.

Synthetic Earthquakes

21. Jennings et al.[4] generated four different types of synthetic accelerograms to represent ground motions for a variety of earthquakes. Type A represents the accelerations in a magnitude 8 earthquake and Type B motion is expected with magnitude 7. Type C is for the epicentral area of a magnitude 5 or 6 earthquake and Type D represents the motion close to the fault for a shallow earthquake of magnitude 4 or 5. Computed values of standardized maximum displacement for these artificial accelerograms are plotted in Figure 13. Newmark's upper bound curve is exceeded here by a factor of about 1.7 for the Type A (magnitude 8) earthquake. The synthetic earthquake of magnitude 8-1/4 modeled by Seed and Idriss[5] (Figure 14) also exceeds Newmark's bounding curves, but by a lesser amount for most values of N/A.

22. The standardized maximum displacements obtained from a synthetic accelerogram developed to fit the response spectra given in the Nuclear

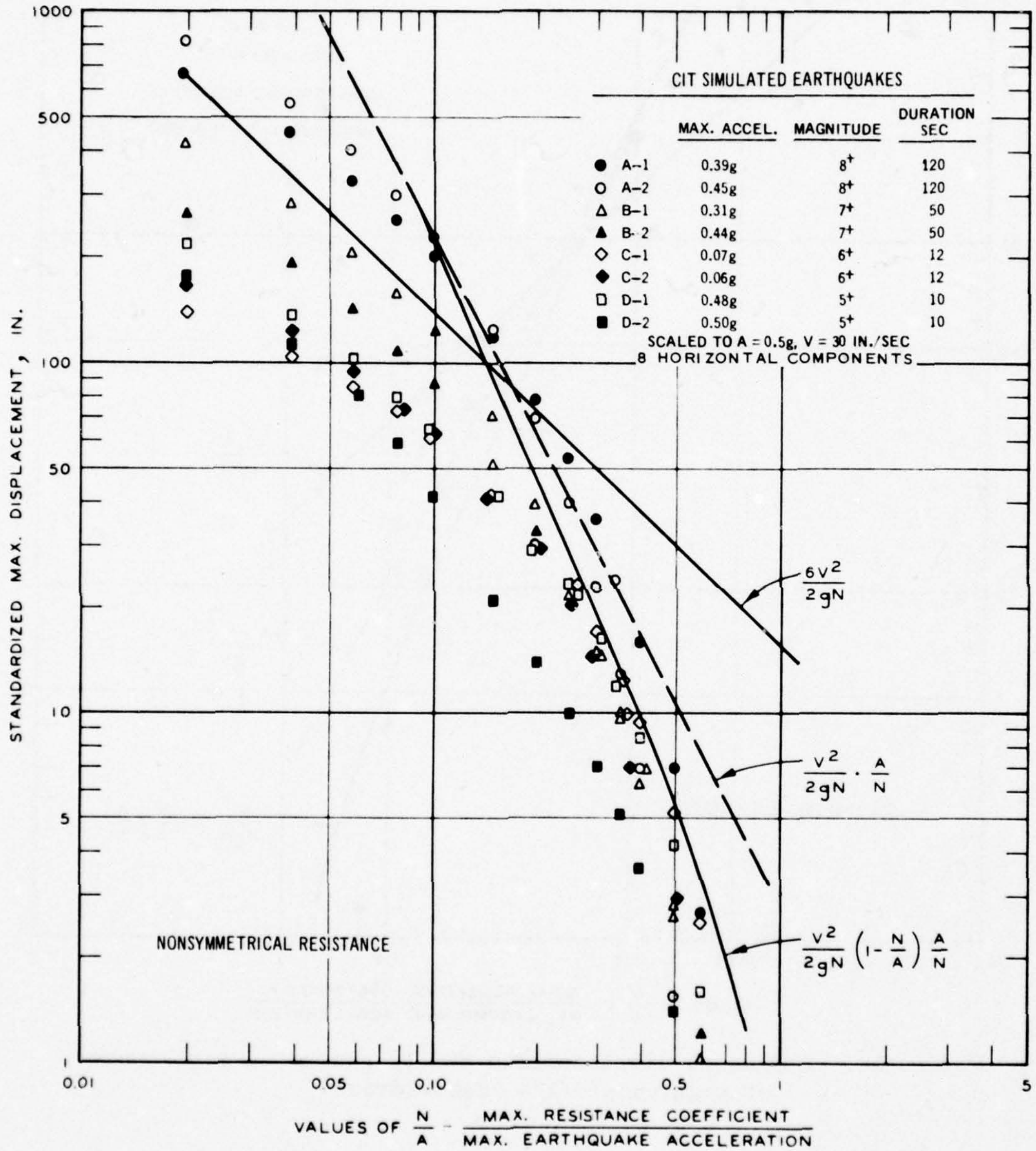


Figure 13. Permanent displacements due to CIT simulated earthquakes by Jennings et al.[4]

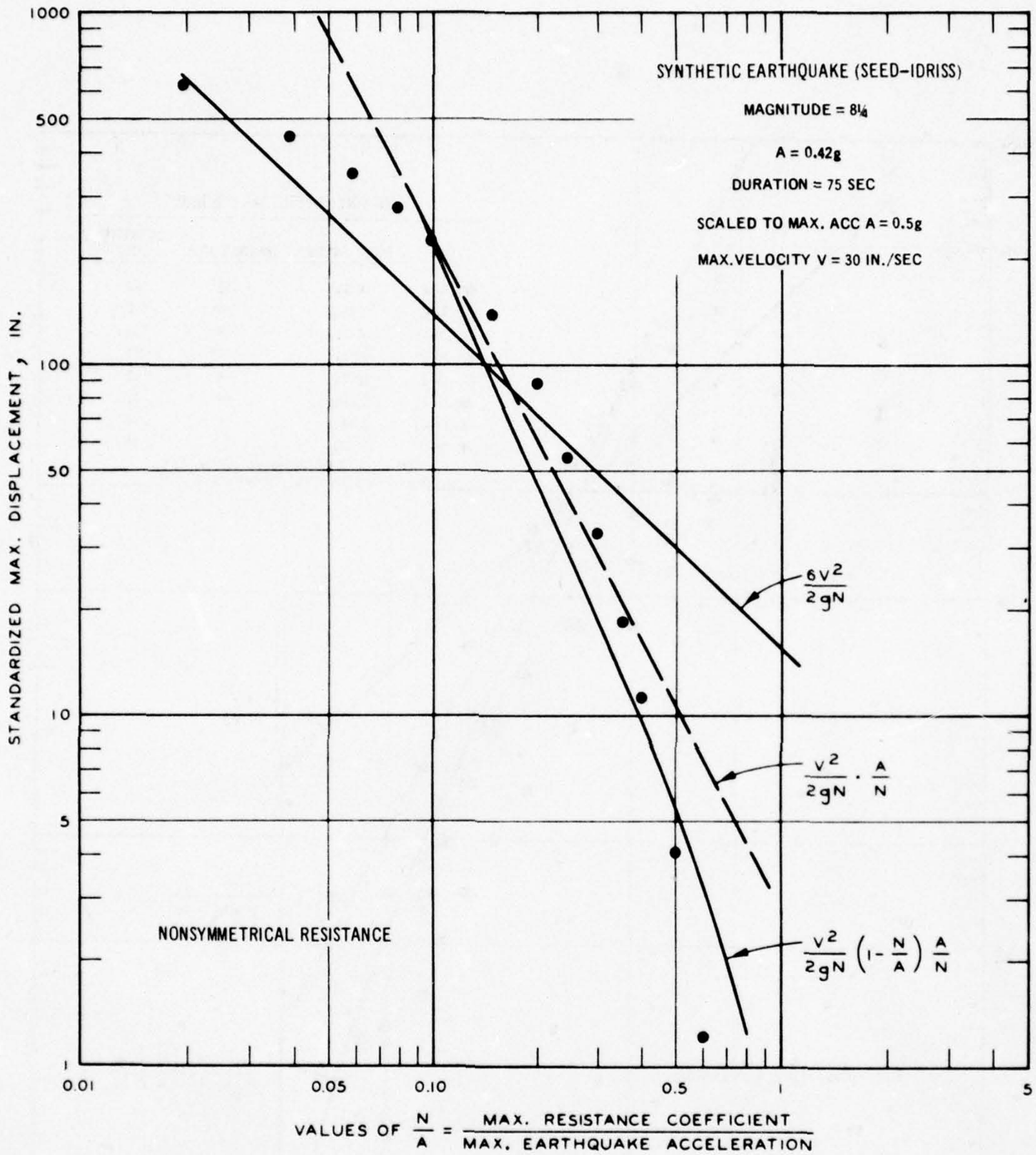


Figure 14. Permanent displacements due to synthetic earthquake of magnitude 8-1/4 (Seed-Idriss[5])

Regulatory Commission Regulatory Guide 1.60[6] are shown in Figure 15. The curve is close to the average curve of the San Fernando earthquake of magnitude 6.5 on rock sites, as shown in Figure 10, but falls far below Newmark's limiting curves and the higher values computed in this study.

23. Upper bound curves for all natural and synthetic earthquake records analyzed in the present study are shown in Figure 16.

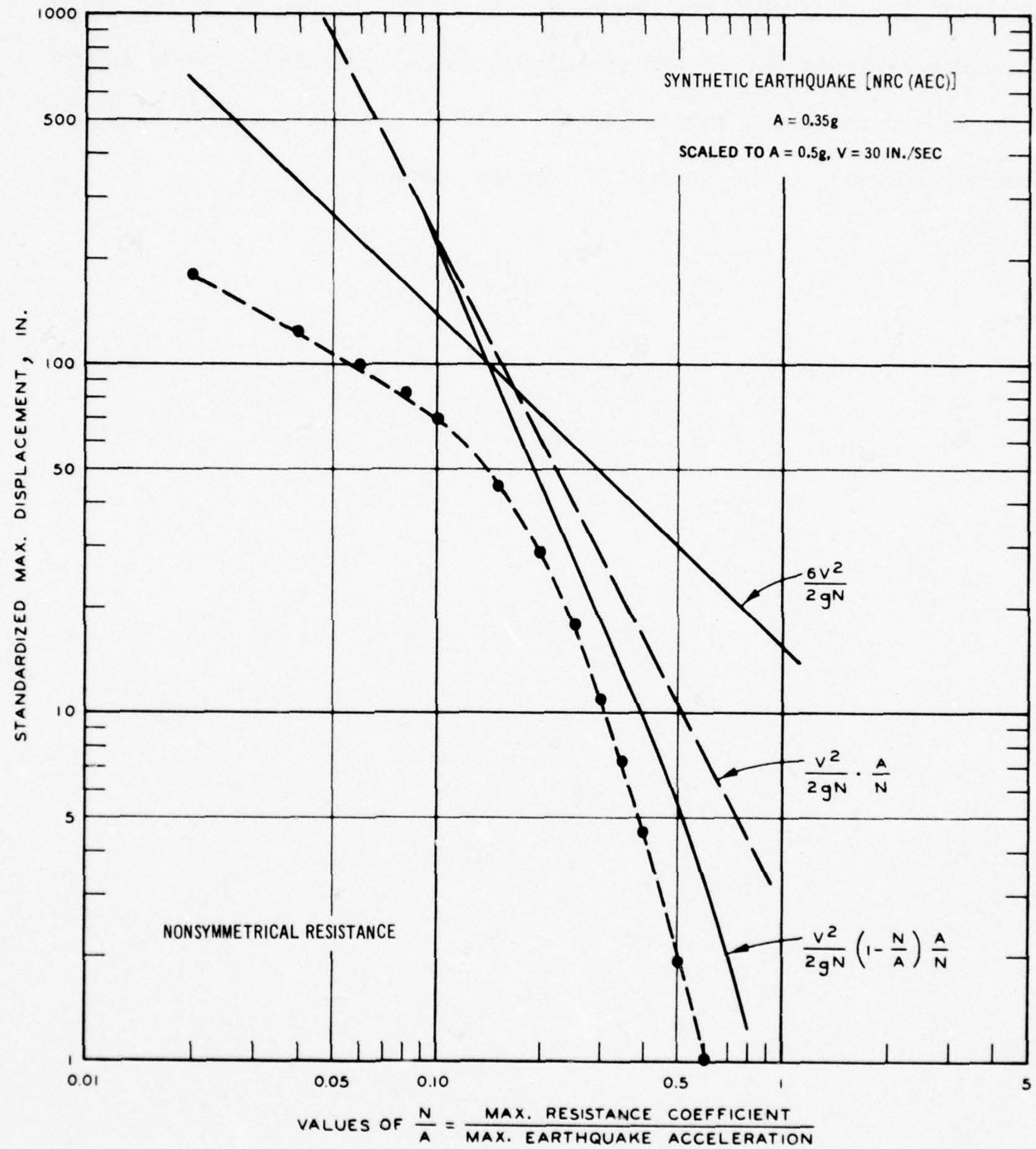


Figure 15. Permanent displacements due to synthetic earthquake corresponding to response spectrum of U. S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.60[6]

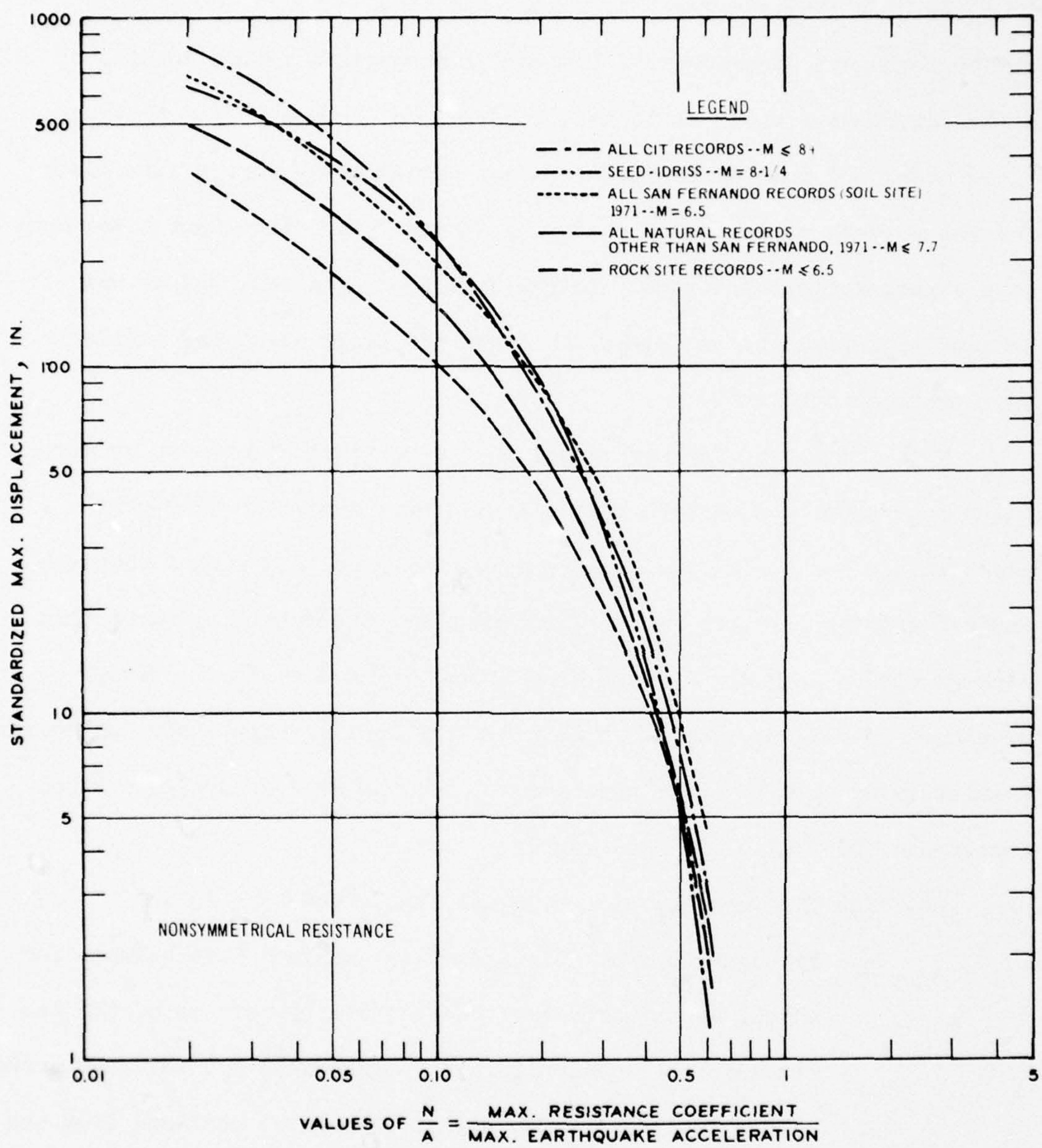


Figure 16. Upper bound envelope curves of permanent displacements for all natural and synthetic records analyzed

PART IV: SUMMARY AND CONCLUSIONS

24. In 1965, Newmark[1] presented the results of calculations of scaled permanent displacements (standardized maximum displacements) of earth embankments under earthquake loading, on the basis of a sliding block model and four earthquake records. Upper bound curves were given for the purpose of earth and rock-fill dam design. Since that time, many more strong-motion earthquake records have been obtained, and it was decided to extend the data base for Newmark's plots using the available new strong-motion data.

25. A total of 169 horizontal and 10 vertical strong-motion earthquake records of the western United States were scaled to 0.5g peak acceleration and 30-in./sec peak velocity and processed with a computer program written for this study. Additionally, the synthetic earthquake records of Jennings et al.[4] and Seed-Idriss,[5] and a synthetic record developed to fit the response spectra of the Nuclear Regulatory Commission Regulatory Guide 1.60[6] were processed. Only the case of nonsymmetrical resistance to sliding was considered.

26. The findings of this study are summarized as follows:

a. New upper bounds of standardized maximum displacement for actual earthquakes were established by records of the San Fernando earthquake of 1971 (magnitude 6.5), which produced values about 1.5 times higher than those obtained from the four earthquake records used in 1965 by Newmark.

b. The greatest standardized maximum displacements found in this study were produced by the Jennings et al. and Seed-Idriss synthetic earthquakes of magnitude 8+, and were

about 1.7 times higher than Newmark's upper bounds.

c. On the basis of comparison of 10 records from rock sites with 47 from soil sites, computed permanent displacements at rock sites are about 75 percent of those at soil sites for earthquakes of equal magnitude, peak acceleration, and peak velocity.

d. Standardized maximum displacement was found to be proportional to the duration of shaking, and consequently to be positively correlated with magnitude, but the trend is weak and considerable scatter exists.

REFERENCES

1. Newmark, N. M., "Effects of Earthquakes on Dams and Embankments," Geotechnique, Vol 15, No. 2, Jan 1965.

2. Sarma, S. K., "Seismic Stability of Earth Dams and Embankments," Geotechnique, Vol 25, No. 4, 1975, pp 743-761.

3. California Institute of Technology, Earthquake Engineering Research Laboratory, "Strong-Motion Earthquake Accelerograms; Corrected Accelerograms and Integrated Ground Velocities and Displacements," Vol II, Parts A-N, 1971-1975, Pasadena, Calif.

4. Jennings, P. C., Housner, G. W., and Tsai, N. C., "Simulated Earthquake Motions," Earthquake Engineering Research Laboratory Report, 1968, California Institute of Technology.

5. Seed, H. B. and Idriss, I. M., "Rock Motion Accelerograms for High Magnitude Earthquakes," EERC 69-7, 1969, Earthquake Engineering Research Center, University of California, Berkeley, Calif.

6. U. S. Nuclear Regulatory Commission (formerly Atomic Energy Commission), Regulatory Guide 1.60, Revision 1, 1973.

APPENDIX A: LIST OF EARTHQUAKE EVENTS

Table A1

List of Earthquake Events

No.	Earthquake Area	Date	Time	Time Zone	Lat ° ' " N	Long. ° ' " W	Depth km	Magnitude	Maximum Intensity
1	Long Beach, Calif.	10 Mar 1933	1754	PST	33 37 00	117 58 00	16.0	6.3	9
2	Southern California	2 Oct 1933	0110	PST	33 47 00	118 08 00	16.0	5.4	6
3	Eureka, Calif.	6 Jul 1934	1449	PST	41 42 00	124 36 00	--	--	5
4	Lower California	30 Dec 1934	0552	PST	32 15 00	115 30 00	16.0	6.5	9
5	Helena, Mont.	31 Oct 1935	1138	MST	46 37 00	111 58 00	--	6.0	8
6	Helena, Mont.	31 Oct 1935	1218	MST	46 37 00	111 58 00	--	--	3
7	Helena, Mont.	21 Nov 1935	2058	MST	46 36 00	112 00 00	--	--	6
8	Helena, Mont.	28 Nov 1935	0742	MST	46 37 00	111 58 00	--	--	6
9	Humboldt Bay, Calif.	6 Feb 1937	2042	PST	40 30 00	125 15 00	--	--	--
10	Imperial Valley, Calif.	12 Apr 1938	0825	PST	32 53 00	115 35 00	16.0	3.0	--
11	Imperial Valley, Calif.	5 Jun 1938	1842	PST	32 54 00	115 13 00	16.0	5.0	--
12	Imperial Valley, Calif.	6 Jun 1938	0435	PST	32 15 00	115 10 00	16.0	4.0	--
13	Northwest California	11 Sep 1938	2210	PST	40 18 00	124 48 00	--	5.5	6
14	Imperial Valley, Calif.	18 May 1940	2037	PST	32 44 00	115 30 00	16.0	6.7	10
15	Northwest California	9 Feb 1941	0145	PST	40 42 00	125 24 00	--	6.4	--
16	Santa Barbara, Calif.	30 Jun 1941	2351	PST	34 22 00	119 35 00	16.0	5.9	8
17	Northern California	3 Oct 1941	0813	PST	40 36 00	124 36 00	--	--	7
18	Torrance-Gardena, Calif.	14 Nov 1941	0042	PST	33 47 00	118 15 00	16.0	5.4	8
19	Borrego Valley, Calif.	21 Oct 1942	0822	PST	32 58 00	116 00 00	16.0	6.5	7
20	Northern California	9 Mar 1949	0429	PST	37 06 00	121 18 00	--	5.3	7
21	Western Washington	13 Apr 1949	1156	PST	47 06 00	122 42 00	--	7.1	8
22	Imperial Valley, Calif.	23 Jan 1951	2317	PST	32 59 00	115 44 00	16.0	5.6	7
23	Northwest California	7 Oct 1951	2011	PST	40 17 00	124 48 00	--	5.8	7
24	Kern County, Calif.	21 Jul 1952	0453	PDT	35 00 00	119 01 00	16.0	7.7	11
25	Kern County, Calif.	23 Jul 1952	--	PDT	35 17 00	118 39 00	--	--	--

(Continued)

(Sheet 1 of 3)

Table A1 (Continued)

No.	Earthquake Area	Date	Time	Time Zone	Lat ° ' " N	Long. ° ' " W	Depth km	Magnitude	Maximum Intensity
26	Northern California	22 Sep 1952	0441	PDT	40 12 00	124 25 00	--	5.5	7
27	Southern California	21 Nov 1952	2346	PST	35 50 00	121 10 00	--	--	7
28	Imperial Valley, Calif.	13 Jun 1953	2017	PST	32 57 00	115 43 00	16.0	5.5	7
29	Wheeler Ridge, Calif.	12 Jan 1954	1534	PST	35 00 00	119 01 00	16.0	5.9	8
30	Central California	25 Apr 1954	1233	PST	36 48 00	121 48 00	--	5.3	7
31	Lower California	12 Nov 1954	0427	PST	31 30 00	116 00 00	16.0	6.3	5
32	Eureka, Calif.	21 Dec 1954	1156	PST	40 47 00	123 52 00	--	6.5	7
33	San Jose, Calif.	4 Sep 1955	1801	PST	37 22 00	121 47 00	--	5.8	7
34	Imperial County, Calif.	16 Dec 1955	2117	PST	33 00 00	115 30 00	16.0	4.3	--
35	Imperial County, Calif.	16 Dec 1955	2142	PST	33 00 00	115 30 00	16.0	3.9	--
36	Imperial County, Calif.	16 Dec 1955	2207	PST	33 00 00	115 30 00	16.0	5.4	7
37	El Alamo, Baja, Calif.	9 Feb 1956	0633	PST	31 42 00	115 54 00	16.0	6.8	--
38	El Alamo, Baja, Calif.	9 Feb 1956	0725	PST	31 42 00	115 54 00	--	6.4	--
39	Southern California	18 Mar 1957	1056	PST	34 07 06	119 13 12	13.8	4.7	6
40	San Francisco, Calif.	22 Mar 1957	1048	PST	37 40 00	122 28 00	--	3.8	5
41	San Francisco, Calif.	22 Mar 1957	1144	PST	37 40 00	122 29 00	--	5.3	7
42	San Francisco, Calif.	22 Mar 1957	1515	PST	37 39 00	122 27 00	--	4.4	5
43	San Francisco, Calif.	22 Mar 1957	1627	PST	37 39 00	122 29 00	--	4.0	5
44	Central California	19 Jan 1960	1926	PST	36 47 00	121 26 00	--	5.0	6
45	Northern California	5 Jun 1960	1718	PST	40 49 00	124 53 00	--	5.7	6
46	Hollister, Calif.	8 Apr 1961	2323	PST	36 30 00	121 18 00	11.0	5.7	7
47	Northern California	4 Sep 1962	0917	PST	40 58 00	124 12 C0	--	5.0	6
48	Puget Sound, Wash.	29 Apr 1965	0729	PST	47 24 00	122 18 00	--	6.5	8
49	Southern California	15 Jul 1965	2346	PST	34 29 06	118 31 18	15.1	4.0	6
50	Parkfield, Calif.	27 Jun 1966	2026	PST	35 57 18	120 29 54	6.0	5.6	7

(Continued)

(Sheet 2 of 3)

Table A1 (Concluded)

No.	Earthquake Area	Date	Time	Time Zone	Lat ° ' " N	Long. ° ' " W	Depth km	Magnitude	Maximum Intensity
51	Gulf of California	7 Aug 1966	0936	PST	31 48 00	114 30 00	16.0	6.3	6
52	Northern California	12 Sep 1966	0841	PST	39 24 00	120 06 00	--	6.3	7
53	Northern California	10 Dec 1967	0407	PST	40 30 00	124 36 00	--	5.8	6
54	Northern California	18 Dec 1967	0925	PST	37 00 36	121 47 18	--	5.2	6
55	Borrego Mtn, Calif.	8 Apr 1968	1830	PST	33 11 24	116 07 42	11.1	6.4	7
56	Lytle Creek, Calif.	12 Sep 1970	0630	PST	34 16 12	117 32 24	8.0	5.4	7
57	San Fernando, Calif.	9 Feb 1971	0600	PST	34 24 42	118 24 00	13.0	6.4	11

(Sheet 3 of 3)

APPENDIX B: STRONG-MOTION DATA, EARTHQUAKES OF WESTERN UNITED STATES, UNIFORMLY PROCESSED AT CALIFORNIA INSTITUTE OF TECHNOLOGY

Table B1

Strong-Motion Data, Earthquakes of Western United States, Uniformly Processed at California Institute of Technology

CIT File No.	Recording Station	Site Classification*	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec²	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
A001	El Centro Site, Imperial Valley	A	5-18-40	32°44' N	S 00° E	341.7	33.4	10.9	3.3	9.3	6.7	VIII	30	230.9	55.6	1.90
				115°27' W	S 90° W	210.1	36.9	19.8	3.1					138.2	41.6	1.38
					Up	206.3	10.8	5.6	9.9						--	
A002	Northwest California Earthquake, Ferndale City Hall	I	10-7-51	40°17' N	S 44° W	102.0	4.8	2.4	10.6	56.3		V				
				124°48' W	N 46° W	109.5	7.4	2.7	5.4							
					Up	26.4	2.2	1.6	8.7							
A003	Kern County Earthquake, Athenaeum	A	7-21-52	35°00' N	S 00° E	46.5	6.2	2.7	3.3	126.0	7.7	VII			--	
				119°02' W	S 90° W	52.1	9.1	2.9	1.8				50	247.2	100.5	4.44
					Up	29.3	4.5	3.0	4.3						--	
A004	Kern County Earthquake, Taft Lincoln School	A	7-21-52	35°00' N	N 21° E	152.7	15.7	6.7	4.2	43.0	7.7	VII		268.7	85.3	2.09
				119°02' W	S 69° E	175.9	17.7	9.2	5.2				54	294.3	74.8	2.37
					Up	102.9	6.7	5.0	11.5						--	
A005	Kern County Earthquake, Santa Barbara Courthouse	A	7-21-52	35°00' N	N 42° E	87.8	11.8	4.6	2.9	89.5	7.7	VII	54	366.2	136.2	3.10
				119°02' W	S 48° E	128.6	19.3	5.8	3.0				60	192.9	70.1	3.61
					Up	43.6	5.0	2.2	3.8						--	
A006	Kern County Earthquake, Hollywood Storage Basement	A	7-21-52	35°00' N	S 00° W	54.1	6.1	5.1	7.4	119.5	7.7	VII	82	466.7	150.7	3.94
				119°02' W	N 90° E	43.5	9.4	5.9	2.9				82	214.7	90.8	2.62
					Up	22.5	4.2	2.2	2.8						--	
A007	Kern County Earthquake, Hollywood Storage P. E. Lot	A	7-21-52	35°00' N	S 00° W	58.1	6.6	4.5	6.0	119.5	7.7	VII	79	493.1	145.7	2.51
				119°02' W	N 90° E	41.2	8.9	6.4	3.3				79	230.8	102.7	4.04
					Up	20.3	3.0	3.4	7.7						--	
A008	Eureka Earthquake, Eureka Federal Building	I	12-21-54	32°38' N	N 11° W	164.5	31.6	12.4	2.0	24.0	6.5	VII	26	157.9	31.4	1.70
				117°07' W	N 79° E	252.7	29.4	14.1	4.1				30	143.5	41.0	2.70
					Up	81.3	8.2	4.7	5.7						--	
A009	Eureka Earthquake, Ferndale City Hall	I	12-21-54	32°38' N	N 44° E	155.7	35.6	14.2	1.7	40.4	6.5	VII	20	167.7	53.0	5.20
				117°07' W	N 46° W	197.3	26.0	9.6	2.8				20	187.0	52.3	3.20
					Up	41.9	7.6	3.9	2.8						--	
A010	San Jose Earthquake, San Jose Bank of America Basement	A	9-4-55	37°22' N	N 31° W	100.2	10.8	2.8	2.4	9.8	5.5	VII	30	70.4	17.7	1.39
				121°53' W	N 59° E	105.8	4.4	1.7	9.3						--	
					Up	44.2	1.2	1.2	6.8						--	
A011	El Alamo, Baja, California Earthquake, El Centro Site, Imperial Valley Irrigation District	A	2-9-56	31°45' N	S 00° W	32.4	4.0	2.4	4.9	125.9	6.8	VI	70		--	
				115°55' W	S 90° W	50.1	7.0	4.1	4.2					427.9	145.8	2.91
					Up	12.4	2.9	1.6	2.4						--	
A012	El Alamo, Baja, California Earthquake, El Centro Site, Imperial Valley Irrigation District (Aftershock)		2-9-56	31°45' N	S 00° W	11.8	1.9	1.7	5.6	125.9						
				115°55' W	S 90° W	15.4	2.7	2.3	4.8							
					Up	3.7	1.8	2.9	3.3							
A013	San Francisco Earthquake, San Francisco Pacific	I	3-22-57	37°40' N	N 45° S	45.9	2.9	1.1	6.0	16.8	5.3	VII			--	
				122°29' W	N 45° W	44.9	5.0	1.4	2.5				26	228.1	73.8	2.02
					Up	26.8	1.5	0.9	10.7						--	
A014	San Francisco Earthquake, San Francisco Alexander Building, Basement	I	3-22-57	37°40' N	N 09° W	41.8	2.9	1.3	6.5	15.2	5.3	VII	25	114.5	33.5	2.51
				122°29' W	N 81° E	45.4	2.1	1.0	10.3						--	
					Up	30.0	1.3	0.4	7.1						--	
A015	San Francisco Earthquake, San Francisco Golden Gate Park	I	3-22-57	37°40' N	N 10° E	81.8	4.9	2.3	7.8	11.8	5.3	VII	12	125.8	23.6	1.07
				122°29' W	S 80° E	102.8	4.6	0.8	3.9						--	
					Up	37.2	1.2	0.7	18.1						--	
A016	San Francisco Earthquake, San Francisco State Building Basement	I	3-22-57	37°40' N	S 09° W	83.8	5.1	1.1	3.5	14.6	5.3	VII				
				122°29' W	S 81° W	55.1	4.0	0.9	3.1							
					Up	43.5	2.3	0.6	4.9							

(Continued)

Note: Locations in California unless otherwise noted.
* A = alluvium, I = intermediate, and HR = hard rock.

(Sheet 1 of 12)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
A017	San Francisco Earthquake, Oakland City Hall Basement	I	3-22-57	37° 40' N 122° 29' W	N 26° E S 64° E Up	39.0 23.7 15.3	2.0 1.2 0.9	1.5 1.1 1.3	14.6 18.1 24.5	24.3	5.3	VI				
A018	Holister Earthquake, Holister City Hall	A	4-8-61	36° 40' N 121° 18' W	S 01° W N 89° W Up	63.4 175.7 49.1	7.8 17.1 4.7	2.8 8.8 2.2	2.9 5.3 4.9	40.0	5.6	VII	30	164.7	-- 36.5 --	0.65
A019	Borrego Mt Earthquake, El Centro Site, Imperial Valley Irrigation District	A	4-8-68	33° 09' N 116° 08' W	S 00° W S 90° W Up	127.8 56.3 29.7	25.8 14.7 3.4	12.2 11.0 3.9	2.3 2.9 10.0	69.8	6.5	VI	60	151.9	39.3 -- --	0.88
A020	Borrego Mt Earthquake, San Diego Light & Power Building	A	4-8-68	33° 09' N 116° 08' W	S 00° W N 90° E Up	29.5 28.9 12.7	6.0 6.1 1.9	4.4 3.0 1.3	3.6 2.3 4.6	109.9	6.5	VI	30	151.9	39.3 -- --	0.88
B021	Long Beach Earthquake, Vernon CMD Building	A	3-10-33	33° 35' N 117° 59' W	N 08° E S 82° E Up	130.6 151.5 149.5	28.7 17.0 12.0	15.5 17.5 7.4	2.5 9.2 7.7	47.8	6.3	VI	30	115.7	22.6 -- --	0.66
B022	Southern California Earthquake, Hollywood Storage Building Penthouse	A	10-2-33	33° 47' N 118° 08' W	S 00° E S 90° W Up	43.3 85.4 26.8	5.2 9.4 1.9	1.8 4.3 0.9	2.9 4.2 6.7	38.2	5.4	V				
B023	Southern California Earthquake, Hollywood Storage Building Basement	A	10-2-33	33° 47' N 118° 08' W	S 00° E S 90° E Up	32.1 26.4 10.7	2.0 2.2 0.9	0.8 0.4 0.5	6.4 2.2 6.6	38.2	5.4	V				
B024	Lower California Earthquake, El Centro Imperial Valley	A	12-30-34	32° 12' N 115° 30' W	N 00° E N 90° E Up	156.8 179.1 68.1	20.5 11.5 8.8	4.2 3.7 5.6	1.6 5.0 4.9	60.8	6.5	VI	30	567.5	-- 157.7 --	1.94
B025	Helena, Montana Earthquake, Helena, Montana, Carroll College	HR	10-31-35	46° 37' N 111° 58' W	N 00° E N 90° E Up	143.5 142.5 87.5	7.3 13.3 9.5	1.4 3.7 2.8	3.8 3.0 2.7	6.6	6.0	VII	5	94.6	-- 23.8 --	1.08
B026	1st Northwest California Earthquake, Ferndale City Hall	I	9-11-38	40° 18' N 124° 48' W	S 45° W N 45° W Up	140.9 87.1 31.6	6.6 6.6 1.4	3.9 1.6 0.6	12.6 3.2 9.7	55.3	5.5	VI				
B027	2nd Northwest California Earthquake, Ferndale City Hall	I	2-9-41	40° 54' N 125° 24' W	S 45° W N 45° W Up	61.3 38.4 19.2	3.5 3.4 2.1	2.0 2.2 1.9	10.0 7.3 8.3	98.4	6.6	VI				
B028	Western Washington Earthquake, District Engineers Office at Army Base	A	4-13-49	46° 06' N 122° 42' W	S 02° W N 88° W Up	66.5 65.9 22.0	8.2 7.9 2.4	2.4 2.7 2.3	2.4 2.8 8.8	57.8	7.1	VIII				
B029	Western Washington Earthquake, Olympia, Washington, Highway Test Laboratory	A	4-13-49	46° 06' N 122° 42' W	S 04° E S 86° W Up	161.6 274.6 90.6	21.4 17.0 6.8	8.5 10.4 4.0	3.0 9.9 7.8	16.8	7.1	VIII	26	582.9	-- 127.1 --	0.50
B030	Northern California Earthquake, Ferndale City Hall	I	9-22-52	40° 12' N 124° 25' W	S 44° W N 46° W Up	53.1 74.1 29.2	6.9 4.7 3.0	2.0 1.9 1.5	2.2 6.4 4.9	43.2	5.5	VI				
B031	Wheeler Ridge, California Earthquake, Taft Lincoln School Tunnel	A	1-12-54	35° 00' N 119° 01' W	N 21° E S 69° E Up	63.9 66.8 35.5	5.8 3.6 2.4	1.7 1.1 2.9	3.2 5.7 17.9	43.0	5.9	VII				
B032	Puget Sound, Washington Earthquake, Olympia, Washington, Highway Test Laboratory	A	4-29-65	47° 24' N 122° 18' W	S 04° E S 86° W Up	134.2 194.3 59.9	8.0 12.7 3.0	2.7 3.8 1.7	5.7 4.6 11.3	61.1	6.5	VII	32	382.2	-- 83.0 --	0.89
B033	Parkfield, California Earthquake, Cholame, Shandon Array No. 2	A	6-27-66	35° 54' N 120° 54' W	N 65° E Down	479.6 202.2	77.9 14.1	26.3 4.3	2.1 4.7	31.9	5.6	VII	14	138.8	25.2 --	0.44

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
B034	Parkfield, California Earthquake, Cholame, Shandon Array No. 5	A	6-27-66	35°54' N 120°54' W	N 05° W N 85° E Down	347.8 425.7 116.9	22.5 25.4 6.8	5.2 7.1 3.4	3.6 4.7 8.6	32.4	5.6	VI	22	198.7	-- 41.9 --	0.02
B035	Parkfield, California Earthquake, Cholame, Shandon Array No. 8	A	6-27-66	35°54' N 120°54' W	N 50° E N 40° W Down	232.6 269.6 77.7	10.8 11.8 4.5	4.4 3.9 2.1	8.8 7.6 8.0	34.1	5.6	VI	20	363.0	-- 69.8 --	1.45
B036	Parkfield, California Earthquake, Cholame, Shandon Array No. 12	A	6-27-66	35°54' W 120°54' W	N 50° E N 40° W Down	52.1 63.2 44.6	7.0 8.0 5.0	4.1 5.7 2.6	4.4 5.6 4.6	36.5	5.6	VI		323.4	-- 62.5 --	0.02
B037	Parkfield, California Earthquake, Temblor No. 2	HR	6-27-66	35°54' N 120°54' W	N 65° W S 25° W Down	264.3 340.8 129.8	14.5 22.5 4.4	4.7 5.5 1.4	5.9 3.7 9.4	31.0	5.6	VII	22	100.6	-- 26.3 --	0.73
B038	Parkfield, California Earthquake, San Luis Obispo Recreation Building	I	6-27-66	35°54' N 120°54' W	N 36° W S 54° W Up	14.2 11.4 6.1	1.1 0.8 1.3	1.2 0.6 0.9	14.1 10.7 3.2	76.1	5.6	V		569.3	101.4 -- --	1.32
B039	2nd Northern California Earthquake, Eureka Federal Building	I	12-10-67	40°30' N 124°36' W	S 11° E N 79° E Down	20.4 19.5 7.7	2.3 2.8 1.5	0.9 1.4 1.3	3.5 3.5 4.4	50.6	5.8	V		102.6	-- 19.0 --	1.02
B040	Borrego Mountain Earthquake, San Onofre SCE Power Plant	I	4-8-68	33°09' N 116°08' W	N 33° E N 57° W Down	40.0 45.5 54.2	3.7 4.2 3.5	1.6 2.9 1.7	4.7 7.5 7.5	134.4	6.5	V		279.7	-- 46.5 --	0.16
C041	San Fernando Earthquake, Pacoima Dam	HR	2-9-71	34°24' N 118°23'42" W	S 16° E S 74° W Down	1148.1 1054.9 696.0	113.2 57.7 58.3	37.7 10.8 19.3	3.4 3.4 3.9	9.1	6.6	X	16 14	162.1 346.9	32.2 92.9 --	0.07 2.19
C042	San Fernando Earthquake, Aftershock at 52.6 sec, Pacoima Dam		2-9-71	34°24' N 118°23'42" W	S 74° W S 16° E Down	27.1 20.7 8.2	2.9 1.5 1.1	1.7 0.9 1.0	5.5 10.2 6.8							
C044	San Fernando Earthquake, Aftershock at 104.6 sec, Pacoima Dam		2-9-71	34°24' N 118°23'42" W	S 74° W S 16° E Down	109.9 113.2 40.5	4.8 4.7 1.8	2.2 2.3 1.0	10.5 11.8 12.5							
C048	San Fernando Earthquake, 8244 Orion Boulevard, 1st Floor, Holiday Inn	A	2-9-71	34°24' W 118°23'42" W	N 00° W S 90° W Down	250.0 131.7 167.5	30.0 23.9 32.0	14.9 13.8 14.6	4.1 3.2 2.4	22.4	6.6	VII	41	398.0	126.1 -- --	1.26
C051	San Fernando Earthquake, 250 East First Street, Basement, Los Angeles	A	2-9-71	34°24' W 118°23'42" W	N 36° E N 54° W Down	97.8 122.7 48.0	17.1 21.9 7.8	9.2 11.6 5.8	3.1 3.0 2.4	42.8	6.6	VII	15	172.0	-- 38.6 --	1.47
C054	San Fernando Earthquake, 445 Figueroa Street, Subbasement, Los Angeles	I,A	2-9-71	34°24' W 118°23'42" W	N 52° W S 38° W Down	147.1 117.0 51.7	17.4 17.3 10.7	11.8 11.8 5.1	5.7 4.6 2.3	41.9	6.6	VII	40 40	247.7 215.9	60.7 58.0 --	2.88 0.31
D056	San Fernando Earthquake, Old Ridge Route, Castaic	I	2-9-71	34°24' N 118°23.7' W	N 21° E N 69° W Down	309.4 265.4 153.3	16.5 27.2 6.2	4.2 9.3 3.5	4.8 3.3 14.0	28.6	6.6	VI	30 -- 30	223.3 188.1	50.7 -- 50.1	0.17 3.86
D057	San Fernando Earthquake, Hollywood Storage Basement	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Up	103.8 148.2 49.8	17.0 19.4 6.0	8.6 13.1 3.8	3.1 5.1 5.2	37.1	6.6	VII	40 40 40	210.1 284.2 236.6	62.0 87.7 63.3	1.55 1.46 1.83
D058	San Fernando Earthquake, Hollywood Storage P. E. Lot	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Up	167.3 207.0 87.0	16.5 21.1 5.0	8.0 14.7 3.0	4.9 6.8 10.4	37.1	6.6	VII	21 21 21	237.6 382.2	53.3 -- 75.3	1.28 1.33
D059	San Fernando Earthquake, 19[illegible] Avenue, The Stars Subbasement	A	2-9-71	34°24' N 118°23.7' W	N 46° W S 44° W Down	133.8 147.1 66.7	9.6 16.7 4.8	7.5 12.2 2.5	10.9 6.4 7.2	39.8	6.6	VII	55 55	479.9 740.4	85.6 -- 105.1	0.99 0.35

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
D062	San Fernando Earthquake, 1640 South Marengo Street, 1st Floor, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	N 38° W S 52° W Down	118.0 130.0 74.6	16.1 17.6 9.0	12.0 6.9 4.1	5.5 2.9 3.8	42.8	6.6	VII	30 30	 231.2	-- 63.9 --	 2.77
D065	San Fernando Earthquake, 3710 Wilshire Boulevard, Basement, Los Angeles	A,I	2-9-71	34°24' N 118°23.7' W	S 00° W S 90° W Down	146.7 155.7 73.1	18.0 22.1 9.0	10.3 12.9 4.9	4.7 4.1 4.4	40.0		VII	17 17 17	155.9 193.5	34.7 -- 58.2	0.39 1.18
D068	San Fernando Earthquake, 7080 Hollywood Boulevard, Basement, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	N 00° E N 90° E Down	81.2 98.0 57.2	12.6 13.3 5.6	8.1 7.2 4.2	4.1 4.0 7.7	35.0	6.6	VII				
E071	San Fernando Earthquake, Wheeler Ridge	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Down	26.5 25.3 13.0	1.9 2.5 2.4	1.4 2.1 3.3	10.2 8.5 7.4	86.0	6.6	V		 259.5	-- 33.1 --	 1.08
E072	San Fernando Earthquake, 4680 Wilshire Boulevard, Basement, Los Angeles	I	2-9-71	34°24' N 118°23.7' W	N 75° W N 15° E Down	82.2 115.0 64.8	20.8 21.5 6.9	14.7 11.7 3.2	2.8 2.9 4.4	39.5	6.6	VII	18 18 18	117.7 329.1	49.3 -- 110.6	0.64 0.35
E075	San Fernando Earthquake, 3470 Wilshire Boulevard, Subbasement, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	N 00° E S 90° W Down	133.8 111.8 47.3	22.3 18.5 7.3	11.4 11.6 3.9	3.1 3.8 3.5	40.1	6.6	VII	22	207.2	48.8 -- --	2.17
E078	San Fernando Earthquake, Water and Power Building, Basement, Los Angeles	I	2-9-71	34°24' N 118°23.7' W	N 50° W S 40° W Down	126.5 169.2 67.2	23.2 16.1 10.2	13.7 8.9 6.4	3.2 5.8 4.1	42.5	6.6	VII	17	179.5	36.2 -- --	2.18
E081	San Fernando Earthquake, Santa Felicia Dam, Outlet Works	I	2-9-71	34°24' N 118°23.7' W	S 08° E S 82° W Down	213.0 198.3 63.7	9.9 6.2 4.5	7.0 4.6 2.8	15.2 23.7 8.8	32.9	6.6	VI	34 34 34	 505.5 525.6	-- 63.2 96.4	 3.27 1.13
E082	San Fernando Earthquake, Santa Felicia Dam, Crest		2-9-71	34°24' N 118°23.7' W	S 15° E S 75° W Down	203.3 174.0 65.0	22.2 18.1 6.2	7.1 5.3 2.8		32.8	6.6	VI	37 37	 274.6	-- 78.3 --	 4.19
E083	San Fernando Earthquake, 3407 6th Street, Basement, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Down	158.2 161.9 55.5	18.3 16.5 8.8	9.0 10.3 4.4	4.2 6.1 1.2	40.0	6.6	VII	25 25 25	228.3 266.7	64.3 -- 72.7	1.75 0.63
F086	San Fernando Earthquake, Vernon, CMD Building	A	2-9-71	34°24' N 118°23.7' W	N 83° W S 07° W Up	104.6 80.5 42.7	17.4 15.1 6.7	14.8 10.7 4.0	5.1 3.8 3.8	49.4	6.6	V		306.8	62.2 -- --	2.36
F087	San Fernando Earthquake, Engineering Building, Santa Ana, Orange County	A	2-9-71	34°24' N 118°23.7' W	S 04° E S 86° W Up	26.8 28.2 16.7	5.0 8.0 2.4	3.6 5.7 1.7	3.8 2.5 4.9	88.5	6.6	VI		 269.7 488.1	-- 77.6 98.5	 0.65 1.91
F088	San Fernando Earthquake, 633 East Broadway, Municipal Service Building, Glendale	A,I	2-9-71	34°24' N 118°23.7' W	S 70° E S 20° W Down	265.7 209.1 131.5	30.7 23.5 15.6	11.1 5.3 5.6	3.1 2.0 3.0	34.1	6.6	VII	27 27 27	 276.0 221.0	-- 117.5 92.6	 4.62 2.95
F089	San Fernando Earthquake, 808 South Olive Street, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	S 53° E S 37° W Down	131.9 139.0 75.3	20.8 20.7 9.9	14.5 11.6 6.0	4.4 3.8 3.7	44.0	6.6	VII	22 22	 181.4	-- 44.3 --	 0.18
F092	San Fernando Earthquake, 2011 Zonal Avenue, Basement, Los Angeles	I	2-9-71	34°24' N 118°23.7' W	S 62° E S 28° W Down	64.2 79.1 48.7	13.8 11.5 7.1	10.3 6.3 3.8	3.5 3.8 3.7	43.1	6.6	VII				
F095	San Fernando Earthquake, 120 North Robertson Boulevard, Subbasement, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	S 88° E S 02° W Down	96.2 83.9 26.5	16.8 17.9 6.2	10.6 12.1 3.9	3.6 3.2 2.7	37.4	6.6	VII				
F098	San Fernando Earthquake, 646 South Olive Avenue, Basement, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	S 53° E S 37° W Down	236.4 192.0 69.2	21.8 18.5 9.6	13.2 13.4 5.3	6.6 7.5 4.0	42.7	6.6	VII	22	218.9	21.3 -- --	0.14

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
F101	San Fernando Earthquake, Edison Company, Colton	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Up	37.5 30.0 19.7	2.5 2.2 1.5	1.1 1.3 1.4	6.6 8.1 12.2	107.6	6.6	V		178.2	72.0 -- --	5.71
F102	San Fernando Earthquake, Fort Tejon, Tejon	HR	2-9-71	34°24' N 118°23.7' W	N 00° E N 90° E Down	24.6 20.6 15.3	1.4 1.3 1.0	0.8 0.7 0.5	10.0 8.5 7.6	68.5	6.6	V		122.6	33.5 -- --	0.71
F103	San Fernando Earthquake, Pumping Plant, Pearblossom	A	2-9-71	34°24' N 118°23.7' W	N 00° E N 90° W Down	91.5 120.5 47.4	4.4 5.4 2.3	2.5 2.4 1.7	11.8 9.9 15.2	45.4	6.6	V		605.1	-- 161.0 --	2.95
F104	San Fernando Earthquake, Oso Pumping Plant, Gorman	I	2-9-71	34°24' N 118°23.7' W	N 00° E N 90° W Down	85.2 103.1 35.5	8.5 6.0 3.8	2.0 2.3 1.2	2.4 6.6 2.9	52.2	6.6	V		180.1	-- 36.7 --	1.21
F105	San Fernando Earthquake, UCLA Reactor Laboratory, Los Angeles	A	2-9-71	34°24' N 118°23.7' W	S 00° W N 90° E Up	83.1 77.6 67.1	8.3 8.5 4.5	4.0 4.9 2.9	4.8 5.3 9.6	38.7	6.6	VII		338.5	55.8 -- --	1.49
G106	San Fernando Earthquake, CIT Seismological Laboratory, Pasadena	HR	2-9-71	34°24'42" N 118°24'00" W	S 00° W S 90° W Down	87.5 188.6 83.5	5.8 11.6 5.7	1.6 5.0 2.3	4.2 7.0 5.9	36.1	6.6	VII	25	204.1	-- 53.9 --	4.07
G107	San Fernando Earthquake, Athenaeum, CIT	A	2-9-71	34°24'42" N 118°24'00" W	N 00° E N 90° E Down	93.5 107.3 92.9	7.9 14.3 6.6	3.0 7.3 2.6	4.5 3.8 5.5	39.8	6.6	VII	26	257.9	-- 78.3 --	0.94
G108	San Fernando Earthquake, CIT Millikan Library	A	2-9-71	34°24'42" N 118°24'00" W	N 00° E N 90° E Down	198.0 181.6 91.2	9.8 26.3 8.7	2.7 6.9 2.4	5.6 4.7 2.9	39.8	6.6	VII	35	540.7	110.9 -- --	0.09
G110	San Fernando Earthquake, CIT Jet Propulsion Laboratory Basement	A,I	2-9-71	34°24'42" N 118°24'00" W	S 82° E S 08° W Down	207.8 139.0 126.3	13.4 9.0 5.7	5.0 2.9 2.6	5.8 5.0 10.1	31.5	6.6	VII	23			
G112	San Fernando Earthquake, 611 West Sixth Street, Basement, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	N 52° W N 38° E Down	101.9 78.5 53.2	17.0 15.7 9.9	11.0 9.2 5.2	3.9 2.9 2.8	40.5	6.6	VII	45 45	154.8	-- 32.1 --	1.99
G114	San Fernando Earthquake, Palmdale Fire Station Storage Room, Palmdale	A	2-9-71	34°24'42" N 118°24'00" W	S 60° E S 30° W Down	110.8 136.2 86.6	14.0 9.3 7.6	3.8 2.7 2.4	2.1 4.3 3.6	32.3	6.6	VI	30	287.2	110.1 -- --	2.51
H115	San Fernando Earthquake, 15250 Ventura Boulevard, Basement	A	2-9-71	34°24'42" N 118°24'00" W	N 11° E N 79° W Down	220.6 146.0 94.5	28.2 23.5 9.3	13.4 10.3 4.3	3.7 2.7 4.7	29.3	6.6	VII	39	351.6	71.4 -- --	1.20
H118	San Fernando Earthquake, 8639 Lincoln Avenue, Basement, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	S 45° E S 45° W Down	33.7 32.7 41.0	11.8 9.1 6.9	8.8 7.8 3.9	2.1 3.1 3.3	50.2	6.6	VI	76	318.8	130.0 -- --	1.85
H121	San Fernando Earthquake, 900 South Fremont Avenue, Basement, Alhambra	A	2-9-71	34°24'42" N 118°24'00" W	S 90° W S 00° W Down	119.4 112.3 79.2	17.1 10.5 8.2	8.6 4.4 3.4	3.5 4.5 4.0	41.1	6.6	VII	27	253.1	67.4 -- --	2.64
H124	San Fernando Earthquake, 2600 Nutwood Avenue, Basement, Fullerton	A	2-9-71	34°24'42" N 118°24'00" W	S 90° W S 00° W Down	34.9 34.5 14.7	4.4 5.8 2.3	2.1 2.7 1.9	3.8 2.8 5.3	76.8	6.6	VI	34	287.1	-- 82.5 --	1.27
I128	San Fernando Earthquake, 435 North Oakhurst Avenue, Basement, Beverly Hills	A	2-9-71	34°24'42" N 118°24'00" W	N 00° E S 90° W Down	60.9 91.6 36.4	13.2 15.0 5.8	7.2 8.1 2.3	2.5 3.3 2.5							
I131	San Fernando Earthquake, 450 North Roxbury Drive, 1st Floor, Beverly Hills	A	2-9-71	34°24'42" N 118°24'00" W	N 50° E N 40° W Down	184.3 160.6 37.2	17.2 14.1 4.5	9.2 6.1 2.3	5.7 4.9 4.2	38.2	6.6	VI	48	244.7	38.7 -- --	0.34

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
I134	San Fernando Earthquake, 1800 Century Park East, Basement (P3), Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	N 54° E	97.9	16.7	11.3	3.9	38.9	6.6	VII				
					S 36° E	82.3	10.7	6.2	4.5							
					Down	62.5	5.7	2.5	4.8							
I137	San Fernando Earthquake, 15910 Ventura Boulevard, Basement, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	S 81° E	140.2	16.1	7.1	3.8	29.0	6.6	VII			--	
					S 09° W	129.0	22.3	8.4	2.2				39	285.7	122.7	0.56
					Down	99.9	7.9	2.6	4.2						--	
J141	San Fernando Earthquake, Lake Hughes Array No. 1	HR	2-9-71	34°24'42" N 118°24'00" W	N 21° E	145.5	18.0	3.4	1.5	29.6	6.6	VI	22	183.3	57.3	1.76
					S 69° E	108.9	14.4	2.9	1.5						--	
					Down	93.0	11.7	2.9	2.0						--	
J142	San Fernando Earthquake, Lake Hughes Array No. 4	HR	2-9-71	34°24'42" N 118°24'00" W	S 69° E	168.2	5.3	1.2	7.2	26.8	6.6	VI			--	
					S 21° W	143.5	8.6	1.7	3.3				37	204.5	54.2	1.29
					Down	150.8	6.8	1.6	5.2						--	
J143	San Fernando Earthquake, Lake Hughes Array No. 9	HR	2-9-71	34°24'42" N 118°24'00" W	N 21° E	119.3	4.8	2.0	10.4	26.6	6.6	VI	27	331.8	93.2	4.25
					N 69° W	109.4	4.3	2.4	14.2						--	
					Down	71.5	2.9	2.2	18.7						--	
J144	San Fernando Earthquake, Lake Hughes Array No. 12	I	2-9-71	34°24'42" N 118°24'00" W	N 21° E	346.2	14.7	1.8	2.9	23.3	6.6	VI	22		--	
					N 69° W	277.9	12.4	8.9	16.1				22	254.9	72.9	6.46
					Down	105.3	4.1	3.3	20.7						--	
J145	San Fernando Earthquake, 15107 Van Owen Street, Basement, Los Angeles	A	2-9-71	34°24' N 118°23'42" W	S 00° W	113.9	31.5	17.5	2.0	34.9	6.6	VII	40	227.7	97.3	3.23
					S 90° W	103.4	28.8	15.3	1.9						--	
					Down	106.4	18.1	7.0	2.5						--	
J148	San Fernando Earthquake, 616 South Normandie Avenue, Basement, Los Angeles	A,I	2-9-71	34°24' N 118°23'42" W	N 00° E	107.6	16.2	7.3	3.0	39.9	6.6	VII			--	
					S 90° W	112.0	17.5	11.1	4.1				19	185.0	62.2	2.22
					Down	51.6	6.7	3.4	3.9						--	
L166	San Fernando Earthquake, 3838 Lankershim Boulevard, Basement, Los Angeles	I	2-9-71	34°24' N 118°23'42" W	N 00° E	164.2	12.3	4.9	5.3	30.8	6.6	VII			--	
					S 90° W	147.6	15.0	5.4	3.5				26	166.2	49.1	3.79
					Down	69.7	5.0	2.4	6.7						--	
L171	San Fernando Earthquake, Nuclear Power Plant, San Onofre	I	2-9-71	34°24' N 118°23'42" W	N 33° E	12.0	1.8	2.1	7.8	139.8	6.6	V			--	
					N 57° W	15.9	2.8	2.1	4.3				52	152.4	24.3	0.36
					Down	10.3	1.5	2.0	9.1						--	
M176	San Fernando Earthquake, 1150 South Hill Street, Subbasement, Los Angeles	A	2-9-71	34°24' N 118°23'42" W	N 37° E	83.4	20.9	13.7	8.6	42.9	6.6	VII	33	183.0	59.4	1.19
					S 53° E	116.0	17.7	13.7	5.1						--	
					Down	41.6	6.9	4.3	2.3						--	
M179	San Fernando Earthquake, Tehachapi Pumping Plant, CWR Site, Grapevine	I	2-9-71	34°24' N 118°23'42" W	S 00° W	20.8	1.1	0.7	12.0	70.7	6.6	VI			--	
					N 90° E	46.7	2.6	0.9	6.2				13	144.9	39.5	2.02
					Down	38.5	2.0	1.2	11.6						--	
M180	San Fernando Earthquake, 4000 West Chapman Avenue, Basement, Orange	A	2-9-71	34°24' N 118°23'42" W	S 00° W	23.9	5.7	3.5	2.6	84.3	6.6	V			--	
					S 90° W	29.9	8.5	6.5	2.7				95	403.6	120.3	0.34
					Down	18.2	3.9	2.5	3.0						--	
M183	San Fernando Earthquake, 6074 Park Drive, Ground level, Wrightwood	I	2-9-71	34°24' N 118°23'42" W	N 65° W	42.4	3.8	1.2	3.5	70.8	6.6	V		234.9	78.2	3.07
					N 25° E	55.7	2.6	0.9	7.4				20		--	
					Down	22.9	2.0	1.2	6.9						--	
M184	San Fernando Earthquake, 6074 Park Drive, Ground level, Wrightwood	I	2-9-71	34°24' N 118°23'42" W	N 65° E	43.1	4.6	1.2	2.4	70.8	6.6	V	26	290.8	73.4	0.88
					S 25° W	57.2	2.9	0.7	4.8						--	
					Down	24.7	1.8	0.9	6.9						--	
N185	San Fernando Earthquake, Carbon Canyon Dam	I	2-9-71	34°24'42" N 118°24'00" W	S 50° E	67.3	3.3	1.7	10.5	75.6	6.6	V			--	
					S 40° W	67.3	4.5	2.1	7.0				40	440.3	128.3	6.79
					Down	41.5	2.5	1.6	10.6						--	

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec²	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
N186	San Fernando Earthquake,	A	2-9-71	34°24'42" N	S 37° E	95.7	8.8	4.9	6.1	54.1	6.6	VI			--	
	Whittier Narrows Dam			118°24'00" W	S 53° W	94.7	9.7	5.0	5.0				45	405.2	54.3	1.26
					Down	58.6	3.6	2.3	10.4						--	
N187	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 75° W	55.7	3.1	0.7	4.9	72.1	6.6	VI	25	498.0	187.3	8.67
	San Antonio Dam,			118°24'00" W	N 15° E	75.9	3.7	0.8	4.4				25		--	
	Upland				Down	28.3	1.5	0.8	10.1						--	
N188	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 54° E	114.4	17.0	10.8	4.3	38.9	6.6	VII	45	200.5	26.4	0.34
	1880 Century Park East,			118°24'00" W	N 36° W	126.5	12.1	5.4	4.7						--	
	Parking, 1st level,				Down	62.5	5.0	2.4	6.0						--	
	Los Angeles															
N191	San Fernando Earthquake,	I	2-9-71	34°24'42" N	N 65° E	24.7	4.1	2.6	3.8	67.8	6.6	VI				
	2516 Via Tejon, Ground			118°24'00" W	S 25° E	40.1	5.0	3.4	5.4				65			
	level, Palos Verdes				Down	18.9	2.2	1.4	5.5							
	Estates															
N192	San Fernando Earthquake,	I	2-9-71	34°24'42" N	N 29° E	96.7	14.8	7.7	3.4	40.7	6.6	VII			--	
	2500 Wilshire Boulevard,			118°24'00" W	N 61° W	98.9	19.5	7.9	2.1				25	110.9	33.3	0.54
	Basement, Los Angeles				Down	42.5	7.7	3.3	2.4						--	
N195	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 57° W	31.0	4.6	2.4	3.5	122.6	6.6	V	99		--	
	San Juan Capistrano			118°24'00" W	N 33° E	40.9	3.6	2.4	7.6				99	655.2	198.8	1.46
					Down	21.0	3.4	1.6	2.4						--	
N196	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 76° W	35.0	9.5	8.0	3.1	75.4	6.6	VI	50	288.0	91.3	1.48
	Long Beach State College,			118°24'00" W	S 14° W	31.2	9.3	6.7	2.4						--	
	Ground level				Down	25.8	4.9	3.8	4.1						--	
N197	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 45° E	25.6	2.2	1.2	6.3	185.0	6.6	V			--	
	Anza Post Office			118°24'00" W	N 45° W	35.4	2.6	1.0	5.2				43	446.3	128.0	4.33
	Storage Room, Anza				Down	14.0	1.4	1.1	7.8						--	
0198	San Fernando Earthquake,	HR	2-9-71	34°24'42" N	S 00° W	176.0	20.5	7.28	3.0	34.0	6.6	VII	23	174.5	34.1	1.92
	Griffith Park Observatory,			118°24'00" W	S 90° W	167.0	14.5	5.45	4.3						--	
	Los Angeles				Down	120.0	7.42	3.38	7.4						--	
0199	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 28° E	137.0	17.60	9.78	4.3	42.0	6.6	VII			--	
	1625 Olympic Boulevard,			118°24'00" W	N 62° W	238.0	21.30	10.30	5.4				30	291.4	69.7	2.47
	Los Angeles				Down	148.0	10.40	5.74	7.8						--	
0204	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 00° E	25.9	8.17	5.81	2.2	73.8	6.6	VI			--	
	205 West Broadway,			118°24'00" W	N 90° E	20.7	9.58	7.27	1.6				69	281.3	123.5	3.67
	Long Beach				Up	12.2	6.12	3.58	1.2						--	
0205	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 21° W	28.4	7.37	6.39	3.3	73.6	6.6	VI			--	
	Terminal Island,			118°24'00" W	S 69° W	28.1	10.30	8.72	2.3				60	275.8	118.6	1.68
	Long Beach				Up	16.1	4.24	2.83	2.5						--	
0206	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 00° E	37.4	3.45	1.30	4.1	108.2	6.6	VI	53	451.7	102.2	3.66
	Hall of Records,			118°24'00" W	N 90° E	43.9	2.86	1.05	5.6						--	
	San Bernardino				Down	18.5	1.52	0.80	6.4						--	
0207	San Fernando Earthquake,	HR	2-9-71	34°24'42" N	N 56° E	64.6	3.84	1.23	5.4	32.8	6.6	VI			--	
	Fairmont Reservoir,			118°24'00" W	N 34° W	97.0	8.35	1.71	2.4				20	103.7	26.7	1.39
	Fairmont				Up	32.90	3.37	1.73	5.0						--	
0208	San Fernando Earthquake,	I	2-9-71	34°24'42" N	N 42° E	16.40	2.69	1.65	3.7			V				
	University of California,			118°24'00" W	S 48° E	17.00	3.67	2.32	2.9							
	Santa Barbara				Up	11.00	1.69	1.45	5.6							
0210	San Fernando Earthquake,	A	2-9-71	34°24'42" N	S 45° E	34.90	2.86	1.66	7.1		6.6	V				
	Fire Station, Hemet			118°24'00" W	S 45° W	38.40	2.74	1.32	6.7							
					Down	25.00	2.33	1.25	5.8							

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec²	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
0213	San Fernando Earthquake, 1215 Gallery, Hoover Dam	HR	2-9-71	34°24'42" N 118°24'00" W	S 45° E S 45° W Up	0.65 1.23 0.86	0.27 0.29 0.55	0.21 0.19 0.71	1.9 2.8 2.0	378.3	6.6	III				
P214	San Fernando Earthquake, 4867 Sunset Boulevard, Los Angeles	I	2-9-71	34°24'42" N 118°24'00" W	S 89° W S 01° E Down	154.00 156.00 115.00	23.20 16.20 9.84	8.02 7.94 5.15	2.3 4.7 6.1	36.2	6.6	VII	15	122.8	49.1 -- --	3.25
P217	San Fernando Earthquake, 3345 Wilshire Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	S 00° W N 90° E Down	108.00 88.10 60.10	14.70 16.10 7.07	9.94 9.09 4.61	5.0 3.1 5.5	40.0	6.6	VII	35	294.0	88.1 -- --	1.60
P220	San Fernando Earthquake, 666 West 19th Street, Costa Mesa	I	2-9-71	34°24'42" N 118°24'00" W	S 00° W N 90° E Down	24.10 34.30 9.29	7.01 5.78 3.47	6.92 6.70 2.32	3.4 6.9 1.8	95.8	6.6	VI	60	698.5	-- 137.3 --	2.49
P221	San Fernando Earthquake, Santa Anita Reservoir, Arcadia	HR	2-9-71	34°24'42" N 118°24'00" W	N 03° E N 87° W Down	137.00 165.00 47.60	5.29 6.66 4.46	3.15 5.91 2.46	15.4 22.0 5.8	43.3	6.6	VI	28	231.7	-- 63.5 --	1.73
P222	San Fernando Earthquake, Navy Laboratory, Port Hueneme	A	2-9-71	34°24'42" N 118°24'00" W	S 00° W S 90° W Up	25.90 25.20 10.40	7.25 5.51 3.19	4.54 4.92 2.17	2.2 4.1 2.2	79.3	6.6	VI	58	336.6	137.7 -- --	1.73
P223	San Fernando Earthquake, Puddingstone Reservoir, San Dimas	HR	2-9-71	34°24'42" N 118°24'00" W	N 55° E N 35° W Down	69.70 53.20 37.80	4.60 4.39 2.24	2.07 1.82 1.79	6.8 5.0 13.5	65.0	6.6	V	32	327.4	71.4 -- --	1.86
P231	San Fernando Earthquake, 9841 Airport Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	N 00° E S 90° W Up	41.30 37.70 17.90	10.60 13.30 5.68	8.28 10.20 3.47	3.0 2.2 1.9	51.7	6.6	VI	30	159.9	-- 77.5 --	0.45
Q233	San Fernando Earthquake, 14724 Ventura Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	S 12° W N 78° W Up	243.00 197.00 96.00	31.50 17.80 9.65	18.30 9.46 3.82	4.5 5.9 3.9	29.3	6.6	VII	36 36	257.6 371.0	66.5 89.2 --	1.68 2.58
Q236	San Fernando Earthquake, 1760 North Orchid Avenue, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	South East Up	167.00 122.00 73.20	13.40 10.30 7.49	6.13 5.85 1.87	5.7 6.7 2.4	34.9	6.6	VII	30 30	372.1	77.6 -- --	1.94
Q239	San Fernando Earthquake, 9100 Wilshire Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	South East Up	119.00 161.00 40.50	17.20 19.10 7.16	9.79 11.60 2.88	3.9 5.1 2.3	38.0	6.6	VII	36 36	255.9 297.7	63.5 54.3 --	2.48 1.49
Q241	San Fernando Earthquake, 800 West First Street, Los Angeles	I	2-9-71	34°24'42" N 118°24'00" W	N 37° E N 53° W Up	86.80 138.00 60.80	17.90 19.60 8.73	9.22 9.98 5.08	2.5 3.6 4.0	41.8	6.6	VII	25 25	160.7 221.8	52.4 50.4 --	1.42 1.75
R244	San Fernando Earthquake, 222 Figueroa Street, Los Angeles	A or I	2-9-71	34°24'42" N 118°24'00" W	N 53° W S 37° W Up	149.00 126.00 43.20	18.30 18.70 8.50	9.80 9.93 4.36	4.4 3.6 2.6	41.9	6.6	VII	20	191.8	45.6 -- --	1.69
R246	San Fernando Earthquake, 6464 Sunset Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	South East Up	115.00 106.00 74.10	16.70 18.30 7.07	8.29 10.40 1.99	3.4 3.3 3.0	35.7	6.6	VII	23	198.4	57.2 -- --	1.49
R248	San Fernando Earthquake, 6430 Sunset Boulevard, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	South East Up	184.00 174.00 88.90	19.70 18.20 6.33	7.68 10.20 2.76	3.6 5.4 6.1	35.7	6.6	VII	28	227.7	59.2 -- --	1.68
R249	San Fernando Earthquake, 1900 Avenue of the Stars, Los Angeles	A	2-9-71	34°24'42" N 118°24'00" W	N 44° E S 46° E Up	79.80 84.10 57.30	16.20 10.00 4.56	11.40 7.34 2.03	3.5 6.2 5.6	39.2	6.6	VII				
R251	San Fernando Earthquake, 234 South Figueroa Street, Los Angeles	A or I	2-9-71	34°24'42" N 118°24'00" W	N 37° E S 53° E Up	195.00 188.00 67.50	16.70 18.70 7.78	8.93 9.49 4.75	6.2 5.1 5.3	41.8	6.6	VII	20	189.6	-- 34.8 --	0.18

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
R253	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 30° W	242.00	19.20	11.40	7.5	42.0	6.6	VII	25	280.2	64.5	1.44
	533 South Fremont Avenue,			118°24'00" W	S 60° W	220.00	18.00	12.40	8.4						--	
	Los Angeles				Up	81.60	9.88	5.40	4.5						--	
S255	San Fernando Earthquake,	I	2-9-71	34°24'42" N	N 08° E	123.00	22.50	15.80	3.8	38.9	6.6	VII	21	206.4	61.5	0.69
	6200 Wilshire Boulevard,			118°24'00" W	N 82° W	128.00	21.90	10.90	2.9						--	
	Los Angeles				Up	46.80	5.20	2.65	4.6						--	
S258	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 29° E	56.30	17.20	10.30	2.0	44.6	6.6	VII				
	3440 University Avenue,			118°24'00" W	S 61° E	83.30	18.50	10.50	2.6							
	Los Angeles				Up	54.50	7.14	3.56	3.8							
S261	San Fernando Earthquake,	A	2-9-71	34°24'42" N	N 59° E	97.70	18.30	12.20	3.6	39.6	6.6	VII	39	200.1	56.5	0.83
	1177 Beverly Drive,			118°24'00" W	N 31° W	107.00	11.20	5.92	5.0						--	
	Los Angeles				Up	64.00	4.95	2.26	5.9						--	
S262	San Fernando Earthquake,	I	2-9-71	34°24'42" N	N 83° W	68.30	25.70	16.50	1.7	39.0	6.6	VII	25	100.8	47.4	1.46
	5900 Wilshire Boulevard,			118°24'00" W	S 07° W	93.60	27.80	13.70	1.7				20	118.6	42.0	1.57
	Los Angeles				Up	32.90	6.17	2.74	2.4						--	
S265	San Fernando Earthquake,	I	2-9-71	34°24'42" N	South	104.00	17.80	8.69	2.9	39.9	6.6	VII			--	
	3411 Wilshire Boulevard,			118°24'00" W	West	125.00	18.20	12.60	4.8				21	200.1	51.7	0.43
	Los Angeles				Up	53.70	6.79	3.56	4.1						--	
S266	San Fernando Earthquake,	A	2-9-71	34°24'42" N	North	153.00	17.50	8.04	4.0	40.0	6.6	VII			--	
	3550 Wilshire Boulevard,			118°24'00" W	West	129.00	21.40	11.60	3.3				30	175.6	60.2	0.74
	Los Angeles				Up	54.20	7.08	3.15	3.4						--	
S267	San Fernando Earthquake,	A	2-9-71	34°24'42" N	North	55.50	13.50	8.49	2.6	52.0	6.6	VI	49	157.9	40.3	0.70
	5260 Century Boulevard,			118°24'00" W	East	61.50	13.80	9.38	3.0				49	218.9	58.6	0.25
	Los Angeles				Up	25.40	5.42	3.64	3.1						--	
T286	El Centro, Imperial Valley	A	10-21-47	32°58'00" N	North	58.40	6.22	4.24	6.4	46.5	6.5	VI	30	531.4	141.5	1.27
	Irrigation District			116°00'00" W	East	46.50	6.05	3.33	4.2						--	
					Up	25.10	1.58	0.79	7.9						--	
T287	El Centro, Imperial Valley	A	1-23-51	32°59'00" N	North	30.30	2.98	1.95	6.6	27.5	5.6	VI	30	323.2	79.0	2.79
	Irrigation District			115°44'00" W	East	27.50	3.09	1.00	2.9						--	
					Up	13.20	1.21	0.89	8.0						--	
T288	El Centro, Imperial Valley	A	6-13-53	32°57'00" N	North	7.21	1.39	1.31	6.8	23.6	5.5	V			--	
	Irrigation District			115°43'00" W	East	35.80	6.32	1.51	1.4				30	234.2	61.3	2.92
					Up	16.80	0.88	0.98	21.3						--	
T289	El Centro, Imperial Valley	A	11-12-54	31°30'00" N	North	24.10	3.76	0.99	1.7	149.8	6.3	IV			--	
	Irrigation District			116°00'00" W	East	27.00	3.17	2.66	7.1				30	201.8	71.0	1.46
					Up	6.74	0.95	1.09	8.1						--	
T292	El Centro, Imperial Valley	A	12-16-55	33°00'00" N	North	62.50	4.60	2.06	6.1	23.5	5.4	VI			--	
	Irrigation District			115°30'00" W	East	71.00	5.16	2.19	5.8				30	310.1	75.1	4.27
					Up	56.40	1.54	0.62	14.7						--	
T293	El Centro, Imperial Valley	A	8-7-66	31°48'00" N	North	13.50	2.43	2.02	4.6	148.1	6.3	VI				
	Irrigation District			114°30'00" W	East	14.70	2.40	1.66	4.2							
					Up	4.96	1.36	1.72	4.6							
U294	City Hall, Ferndale	I	7-6-34	41°42'00" N	N 45° W	14.50	1.40	1.12	8.3	128.9		IV				
				124°36'00" W	S 45° W	14.60	1.05	1.26	16.7							
					Up	5.98	0.82	1.03	9.2							
U295	Federal Building,	HR	10-31-35	46°37'00" N	North	29.30	0.54	0.32	32.1	5.8		VII				
	Helena, Montana			111°58'00" W	East	25.20	0.39	0.16	26.5							
					Up	7.11	0.52	0.67	17.6							
U297	Helena, Montana,	HR	11-28-35	46°37'00" N	North	74.80	3.22	0.84	6.0	5.8	5.0	VI			--	
	Federal Building			111°58'00" W	East	83.00	3.88	0.99	5.5				20	310.7	50.6	0.72
					Up	31.70	1.42	0.78	12.3						--	

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec²	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
U298	City Hall, Ferndale	I	2-6-37	40°30'00" N	N 45° W	38.40	4.07	0.90	2.1	85.1		V				
				125°15'00" W	S 45° W	35.90	2.71	0.99	4.8							
					Up	13.90	1.59	1.04	5.7							
U299	Santa Barbara Courthouse	A	6-30-41	34°22' N	N 45° E	233.00	21.70	3.74	1.9	35.9	5.9	VIII	15	40.8	12.7	1.96
				119°35' W	S 45° E	172.00	21.60	3.92	1.4						--	
					Up	68.50	3.64	2.59	13.4						--	
U300	City Hall, Ferndale	I	10-3-41	40°36' N	N 45° W	118.00	6.92	2.95	7.3	29.8	6.4	VII	30	366.5	93.4	0.18
				124°36' W	S 45° W	113.00	5.74	2.51	8.6						--	
					Up	37.50	2.56	1.12	6.4						--	
U301	Public Library,	A	3-9-49	37°06' N	N 89° W	193.00	11.70	1.40	2.0	29.3	5.3	VII	30	170.7	32.9	2.39
	Hollister			121°18' W	S 01° W	119.00	8.26	1.71	3.0						--	
					Up	69.50	3.63	0.96	5.1						--	
U305	Public Library,	A	4-25-54	36°48' N	N 89° W	52.00	4.19	2.24	6.6	36.2	5.3	VI	33	284.9	83.8	1.90
	Hollister			121°48' W	S 01° W	48.90	4.52	1.36	3.2						--	
					Up	23.10	1.94	1.06	6.5						--	
U307	Public Library,	A	1-19-60	36°47' N	N 89° W	55.50	5.25	1.85	3.7	8.5	5.0	VI	35	212.6	62.0	0.95
	Hollister			121°26' W	S 01° W	35.30	3.64	1.21	3.2						--	
					Up	23.60	2.10	1.08	5.8						--	
U308	City Hall, Ferndale	I	6-5-60	40°49' N	N 46° W	57.50	3.11	1.21	7.2	60.3	5.7	VI			--	
				124°53' W	S 44° W	73.50	3.60	1.18	6.7				65	568.9	88.5	4.81
					Up	14.40	1.06	0.81	10.4						--	
U309	Public Library,	A	4-8-61	36°30' N	N 89° W	168.00	10.80	3.00	4.3	40.0	5.7	VII	30	177.5	39.8	0.09
	Hollister			121°18' W	S 01° W	74.90	6.28	1.77	3.4						--	
					Up	60.20	4.23	1.99	6.7						--	
U310	Federal Office Building,	A	4-29-65	47°24' N	S 32° E	52.10	5.59	2.55	4.3	22.3	6.5	VIII			--	
	Seattle, Washington			122°18' W	S 58° W	77.50	9.35	5.43	4.8				30	242.3	76.5	2.11
					Up	32.10	8.35	1.62	9.4						--	
U311	Lincoln School Tunnel, Taft	A	6-27-66	35°57'18" N	N 21° E	8.10	2.10	2.53	4.6	130.5	5.6	III	55		--	
				120°29'54" W	S 69° E	11.20	2.21	1.49	3.4					319.6	85.7	1.81
					Up	5.95	1.10	1.50	7.4						--	
U312	City Hall, Ferndale	I	12-10-67	40°30' N	N 46° W	103.00	11.80	1.76	1.3	30.6	5.8	VI			--	
				124°36' W	S 44° W	232.00	11.90	1.66	2.7				35	108.4	9.2	0.00
					Up	32.40	2.69	1.00	4.5						--	
U313	Hollister	A	12-18-67	37°00'36" N	N 89° W	13.10	2.67	2.26	4.2	39.0	5.2	V			--	
				121°47'18" W	S 01° W	16.20	1.74	2.03	10.9				60	553.2	154.2	3.52
					Up	10.00	1.14	1.33	10.2						--	
V314	Los Angeles Subway Terminal	I,A	3-10-33	33°37' N	N 39° E	62.30	17.30	8.21	1.7	54.9	6.3	VII			--	
	Subbasement			117°58' W	N 51° W	95.60	23.60	16.30	2.8				80	293.8	87.6	4.74
					Up	63.60	9.07	5.72	4.4						--	
V315	Public Utilities Building	A	3-10-33	33°37' N	South	192.00	29.40	22.70	5.0	27.2	6.3	VIII	34	213.2	31.7	0.63
	Long Beach			117°58' W	West	155.00	16.50	11.80	6.7				--		--	
					Up	279.00	30.10	26.30	8.1				30	110.5	21.6	0.94
V316	Public Utilities Building,	A	11-14-41	33°47' N	North	39.70	7.61	2.47	1.7	6.2	5.4	VI			--	
	Long Beach			118°15' W	East	53.60	9.32	3.56	2.2				20	160.2	41.0	0.94
					Up	8.47	1.04	0.56	4.4						--	
V317	Los Angeles Chamber of	A	11-14-41	33°47'00" N	S 50° E	14.90	1.33	0.85	7.2	28.5	5.4	VI				
	Commerce Basement			118°15'00" W	S 40° W	11.20	1.42	0.49	2.7							
					Up	6.69	0.79	0.41	4.4							
V319	City Recreation Building, San	I	11-21-52	35°50' N	N 36° W	52.90	3.35	0.80	3.8	76.1	6.0	VI	26	449.2	114.6	3.36
	Luis Obispo			121°10' W	S 54° W	35.40	2.89	1.26	5.3						--	
					Up	26.30	2.63	1.20	4.6						--	
V320	Southern Pacific Building	A	3-22-57	37°40' N	N 45° E	2.02	0.28	0.32	8.2	16.2	3.8	V				
	Basement, San Francisco			122°28' W	N 45° W	2.42	0.33	0.43	9.6							
	(Foreshock)				Up	1.52	0.33	0.46	6.4							

(Continued)

Table B1 (Continued)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
V322	San Francisco, South Pacific Building	A	3-22-57	37°39'00" N 122°27'00" W	N 45° S N 45° W Up	8.56 24.50 6.05	0.83 2.61 0.88	0.40 1.17 0.88	5.0 4.2 6.9	17.3	4.4	V				
V323	San Francisco, Alexander Building	I	3-22-57	37°39'00" N 122°27'00" W	N 81° E N 09° W Up	15.60 18.50 5.80	0.82 0.98 0.88	0.26 0.72 0.86	6.0 13.9 6.4	15.60	4.4	V				
V328	Southern Pacific Building Basement, San Francisco (Aftershock)	A	3-22-57	37°39' N 122°29' W	N 45° E N 45° W Up	2.07 9.00 2.79	0.42 0.91 0.54	0.38 0.48 0.51	4.5 5.2 4.9	18.30	4.0	V	20	173.1	-- 34.7 --	0.84
V329	Port Hueneme	A	3-18-57	34°07'06" N 119°13'12" W	South West Up	163.00 86.80 24.70	17.90 8.85 1.93	4.02 2.61 0.48	2.0 2.9 3.2	5.4	4.7	VI				
V330	Federal Building, Eureka	I	9-4-62	40°58' N 124°12' W	N 79° E S 11° E Up	45.30 47.30 12.90	3.52 2.67 1.50	1.70 1.18 2.00	6.2 7.8 11.5	19.0	5.0	VI	70	189.2	28.7 -- --	1.67
V331	Old Ridge Route (CWR Site), Castiac	I	7-15-65	34°29'06" N 118°31'18" W	South East Down	40.40 35.90 26.20	2.12 1.13 0.58	0.87 0.42 0.18	7.8 11.8 14.0	21.2	4.0	V	30	57.9	15.5 -- --	0.52
V332	Sacramento, Pacific Telephone and Telegraph	A	9-12-66	39°24'00" N 120°06'00" W	South East Up	14.40 12.40 8.07	1.57 1.74 0.83	0.74 0.75 0.65	4.3 3.1 7.6	151.5	6.3	VI				
W334	6074 Park Drive, Wrightwood	I	9-12-70	34°16'12" N 117°32'24" W	S 65° E S 25° W Down	139.00 194.00 53.00	8.87 9.63 3.18	2.21 1.03 1.44	3.9 2.2 7.5	13.4	5.4	VI	17	155.2	-- 37.2 --	3.84
W335	Cedar Springs, Allen Ranch	HR	9-12-70	34°16'12" N 117°32'24" W	S 85° E S 05° W Down	69.80 54.90 59.30	5.55 1.96 2.56	2.42 2.00 1.15	5.5 28.6 10.4	20.8	5.4	VI				
W336	Cedar Springs, Pump House on dam abutment	I	9-12-70	34°16'12" N 117°32'24" W	S 54° E S 36° W Down	55.90 69.40 36.90	2.94 3.96 1.25	0.78 1.21 0.36	5.0 5.4 8.5	23.8	5.4	VI				
W338	Hall of Records, San Bernardino	A	9-12-70	34°16'12" N 117°32'24" W	North East Down	113.00 57.50 52.50	4.75 3.10 1.85	1.75 1.66 1.54	8.8 9.9 23.6	22.9	5.4	VI	25	197.3	47.1 -- --	4.25
W339	Southern California Edison Company, Colton	A	9-12-70	34°16'12" N 117°32'24" W	South East Up	40.20 35.30 33.60	2.55 1.87 1.30	0.95 0.70 0.72	5.9 7.1 14.3	31.5	5.4	VI	35	131.8	44.8 -- --	1.97
W342	Millikan Library Basement, CIT, Pasadena	A	9-12-70	34°16'12" N 117°32'24" W	North East Down	19.30 18.70 12.30	1.53 1.44 0.68	1.74 1.13 0.52	14.3 10.2 13.8	56.0	5.4	V	24	324.7	83.6 -- --	2.09
W344	J. P. L. Basement, Pasadena	I	9-12-70	34°16'12" N 117°32'24" W	S 82° E S 08° W Down	14.40 24.10 15.40	1.03 2.00 1.86	1.03 2.37 1.44	14.0 14.3 6.4	58.9	5.4	V	24	136.7	-- 15.7 --	0.92
Y370	Southern California Edison Company, Colton	A	4-8-68	33°11'24" N 116°07'42" W	South East Up	21.40 28.10 21.40	3.53 2.71 1.80	4.25 2.11 1.07	7.3 8.1 7.1	146.2	6.4	VI	81	212.8	35.0 -- --	0.47
Y371	Engineering Building, Santa Anna, Orange County	A	4-8-68	33°11'24" N 116°07'42" W	S 04° E S 26° W Up	13.10 11.70 5.65	4.38 4.28 2.21	3.47 2.85 1.94	2.4 1.8 2.2	173.1	6.4	V	82	286.5	102.5 -- --	0.57

(Continued)

Table B1 (Concluded)

CIT File No.	Recording Station	Site Classification	Date of Earthquake	Epicenter Location	Instrument Component	A Peak Acceleration cm/sec^2	V Peak Velocity cm/sec	D Peak Displacement cm	$\frac{AD}{V^2}$	Epicentral Distance km	Richter Magnitude M	Modified Mercalli Intensity	Duration sec	u_s, in., for N/A 0.02	0.1	0.5
Y372	Terminal Island, Southern California Edison Plant, Long Beach	A	4-8-68	33°11'24" N	N 21° W	8.73	3.19	4.98	4.3	205.1	6.4	VI	52	161.5	50.5	2.60
				116°07'42" W	S 69° W	9.51	2.86	2.11	2.5						--	
					Up	5.14	1.75	1.82	3.1						--	
Y373	J. P. L. Basement, Pasadena	A,I	4-8-68	33°11'24" N	S 82° E	7.35	1.35	0.53	2.1	220.3	6.4	VI	30	263.7	76.1	2.81
				116°07'42" W	S 08° W	7.02	1.32	0.96	3.7						--	
					Down	4.89	0.99	0.72	3.6						--	
Y375	Millikan Basement, CIT, Pasadena	A	4-8-68	33°11'24" N	North	9.82	2.20	1.70	3.4	212.9	6.4	VI	52		--	
				116°07'42" W	East	10.30	2.24	1.84	3.8				52	210.9	77.1	1.96
					Down	6.38	1.14	0.85	4.2						--	
Y376	Pasadena, CIT Athenaeum	A	4-8-68	33°11'24" N	South	6.99	2.10	2.02	3.2	212.0	6.4	VI				
				116°07'42" W	West	10.00	2.45	1.62	2.7							
					Up	3.81	0.99	1.05	4.1							
Y377	Southern California Edison Building, Los Angeles	A	4-8-68	33°11'24" N	N 52° W	7.66	2.33	1.98	2.8		6.4	VI				
				116°07'42" W	S 38° W	11.90	3.08	2.31	2.9							
					Up	4.12	1.33	1.36	3.2							
Y378	Subway Terminal Basement, Los Angeles	A,I	4-8-68	33°11'24" N	S 52° E	6.97	2.23	1.07	1.5	218.8	6.4	VI			--	
				116°07'42" W	S 38° W	11.40	3.07	2.30	2.8				30	187.9	58.9	0.36
					Up	5.41	1.23	1.01	3.6						--	
Y379	CMD Building, Vernon	A	4-8-68	33°11'24" N	N 83° W	18.40	4.27	2.50	2.5	212.2	6.4	VI			--	
				116°07"42" W	S 07° W	18.50	4.65	2.69	2.3				60	245.8	79.8	1.34
					Up	6.97	2.38	1.47	1.8						--	
Y380	Hollywood Storage P. E. Lot, Los Angeles	A	4-8-68	33°11'24" N	South	10.90	2.42	2.12	3.9	227.3	6.4	VI			--	
				116°07'42" W	East	12.30	3.18	1.38	1.7				51	231.1	78.5	2.19
					Up	4.79	1.11	1.06	4.1						--	

APPENDIX C: SYNTHETIC EARTHQUAKE RECORDS

Table C1

Synthetic Earthquake Records

Simulated Earthquake Type	Approximate Magnitude	A Maximum Acceleration cm/sec^2	V Maximum Velocity cm/sec	D Maximum Displacement cm	$\frac{AD}{V^2}$	$\frac{V^2}{AD}$	Approximate Predominant Period sec	Total Duration sec
CIT[4] A-1	8+	382.77	58.99	39.83	4.38	0.228	0.50	120
A-2	8+	441.64	55.05	72.97	10.63	0.094	0.35	120
B-1	7	368.12	45.72	33.17	5.84	0.171	0.20	50
B-2	7	308.70	48.26	22.22	2.94	0.339	0.22	50
C-1	6	66.93	6.65	1.36	2.06	0.486	0.15	12
C-2	6	57.23	6.09	0.88	1.36	0.736	0.20	12
D-1	5	470.40	26.67	4.88	3.23	0.310	0.15	10
D-2	5	490.00	28.94	6.84	4.00	0.245	0.15	10
Seed-Idriss[5]	8-1/4	412.21	57.76	--	--	--	0.40	73

APPENDIX D: NOTATION

A	Maximum ground acceleration as a fraction of g
D	Maximum displacement
g	Acceleration of gravity
M	Earthquake magnitude
N	Ground acceleration, as a fraction of g, required to make factor of safety unity
P	Resultant of normal stress on slip surface
p	Normal stress on slip surface
S	Resultant of shear stress on slip surface
s	Shear stress on slip surface
Subscript s	Scaled value
t	Time
t_m	Time at cessation of relative motion
t_o	Time at end of acceleration pulse
u_m	Displacement of sliding mass relative to ground
u_s	Standardized maximum displacement; i.e., scaled permanent displacement of sliding mass for $A = 0.5$ and $V = 30$ in./sec
v	Velocity
v_b	Instantaneous velocity of sliding mass
v_g	Instantaneous ground velocity at time t
V	Maximum ground velocity
W	Weight of sliding mass
β	Inclination of the resultant of shearing resistance, S, with respect to horizontal
θ	Inclination of critical earthquake acceleration to horizontal

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Franklin, Arley G
  Earthquake resistance of earth and rock-fill dams; Report 5: Permanent displacements of earth embankments by Newmark sliding block analysis / by Arley G. Franklin, Frank K. Chang. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.
  38, [21] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; S-71-17, Report 5)
  Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under CWIS No. 31144.
  References: p. 38.

1. Dam stability. 2. Displacement. 3. Earth dams. 4. Earthquake engineering. 5. Earthquake resistant structures. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; S-71-17, Report 5.
TA7.W34m no.S-71-17 Report 5